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DOE FUNDAMENTALS HANDBOOK

ENGINEERING SYMBOLOGY, PRINTS, AND DRAWINGS

Volume 1 of 2



U.S. Department of Energy
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ABSTRACT

The *Engineering Symbolology, Prints, and Drawings* Handbook was developed to assist nuclear facility operating contractors in providing operators, maintenance personnel, and technical staff with the necessary fundamentals training to ensure a basic understanding of engineering prints, their use, and their function. The handbook includes information on engineering fluid drawings and prints; piping and instrument drawings; major symbols and conventions; electronic diagrams and schematics; logic circuits and diagrams; and fabrication, construction, and architectural drawings. This information will provide personnel with a foundation for reading, interpreting, and using the engineering prints and drawings that are associated with various DOE nuclear facility operations and maintenance.

Key Words: Training Material, Print Reading, Piping and Instrument Drawings, Schematics, Electrical Diagrams, Block Diagrams, Logic Diagrams, Fabrication Drawings, Construction Drawings, Architectural Drawings

FOREWORD

The *Department of Energy (DOE) Fundamentals Handbooks* consist of ten academic subjects, which include Mathematics; Classical Physics; Thermodynamics, Heat Transfer, and Fluid Flow; Instrumentation and Control; Electrical Science; Material Science; Mechanical Science; Chemistry; Engineering Symbolology, Prints, and Drawings; and Nuclear Physics and Reactor Theory. The handbooks are provided as an aid to DOE nuclear facility contractors.

These handbooks were first published as Reactor Operator Fundamentals Manuals in 1985 for use by DOE category A reactors. The subject areas, subject matter content, and level of detail of the Reactor Operator Fundamentals Manuals were determined from several sources. DOE Category A reactor training managers determined which materials should be included, and served as a primary reference in the initial development phase. Training guidelines from the commercial nuclear power industry, results of job and task analyses, and independent input from contractors and operations-oriented personnel were all considered and included to some degree in developing the text material and learning objectives.

The *DOE Fundamentals Handbooks* represent the needs of various DOE nuclear facilities' fundamental training requirements. To increase their applicability to nonreactor nuclear facilities, the Reactor Operator Fundamentals Manual learning objectives were distributed to the Nuclear Facility Training Coordination Program Steering Committee for review and comment. To update their reactor-specific content, DOE Category A reactor training managers also reviewed and commented on the content. On the basis of feedback from these sources, information that applied to two or more DOE nuclear facilities was considered generic and was included. The final draft of each of the handbooks was then reviewed by these two groups. This approach has resulted in revised modular handbooks that contain sufficient detail such that each facility may adjust the content to fit their specific needs.

Each handbook contains an abstract, a foreword, an overview, learning objectives, and text material, and is divided into modules so that content and order may be modified by individual DOE contractors to suit their specific training needs. Each handbook is supported by a separate examination bank with an answer key.

The *DOE Fundamentals Handbooks* have been prepared for the Assistant Secretary for Nuclear Energy, Office of Nuclear Safety Policy and Standards, by the DOE Training Coordination Program. This program is managed by EG&G Idaho, Inc.

OVERVIEW

The *Department of Energy Fundamentals Handbook* entitled *Engineering Symbolology, Prints, and Drawings* was prepared as an information resource for personnel who are responsible for the operation of the Department's nuclear facilities. A basic understanding of engineering prints and drawings is necessary for DOE nuclear facility operators, maintenance personnel, and the technical staff to safely operate and maintain the facility and facility support systems. The information in the handbook is presented to provide a foundation for applying engineering concepts to the job. This knowledge will improve personnel understanding of the impact that their actions may have on the safe and reliable operation of facility components and systems.

The *Engineering Symbolology, Prints, and Drawings* handbook consists of six modules that are contained in two volumes. The following is a brief description of the information presented in each module of the handbook.

Volume 1 of 2

Module 1 - Introduction to Print Reading

This module introduces each type of drawing and its various formats. It also reviews the information contained in the non-drawing areas of a drawing.

Module 2 - Engineering Fluid Diagrams and Prints

This module introduces engineering fluid diagrams and prints (P&IDs); reviews the common symbols and conventions used on P&IDs; and provides several examples of how to read a P&ID.

Module 3 - Electrical Diagrams and Schematics

This module reviews the major symbols and conventions used on electrical schematics and single line drawings and provides several examples of reading electrical prints.

OVERVIEW (Cont.)

Volume 2 of 2

Module 4 - Electronic Diagrams and Schematics

This module reviews electronic schematics and block diagrams. It covers the major symbols used and provides several examples of reading these types of diagrams.

Module 5 - Logic Diagrams

This module introduces the basic symbols and common conventions used on logic diagrams. It explains how logic prints are used to represent a component's control circuits. Truth tables are also briefly discussed and several examples of reading logic diagrams are provided.

Module 6 - Engineering Fabrication, Construction, and Architectural Drawings

This module reviews fabrication, construction, and architectural drawings and introduces the symbols and conventions used to dimension and tolerance these types of drawings.

The information contained in this handbook is by no means all encompassing. An attempt to present the entire subject of engineering drawings would be impractical. However, the *Engineering Symbolology, Prints, and Drawings* handbook does present enough information to provide the reader with a fundamental knowledge level sufficient to understand the advanced theoretical concepts presented in other subject areas, and to improve understanding of basic system operation and equipment operations.

**Department of Energy
Fundamentals Handbook**

**ENGINEERING SYMBOLOGY, PRINTS,
AND DRAWINGS**

Module 1

Introduction to Print Reading

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TERMINAL OBJECTIVE

- 1.0 Given an engineering print, **READ** and **INTERPRET** the information contained in the title block, the notes and legend, the revision block, and the drawing grid.

ENABLING OBJECTIVES

- 1.1 **STATE** the five types of information provided in the title block of an engineering drawing.
- 1.2 **STATE** how the grid system on an engineering drawing is used to locate a piece of equipment.
- 1.3 **STATE** the three types of information provided in the revision block of an engineering drawing.
- 1.4 **STATE** the purpose of the notes and legend section of an engineering drawing.
- 1.5 **LIST** the five drawing categories used on engineering drawings.

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INTRODUCTION TO PRINT READING

A thorough knowledge of the information presented in the title block, the revision block, the notes and legend, and the drawing grid is necessary before a drawing can be read. This information is displayed in the areas surrounding the graphic portion of the drawing.

- | | |
|---------------|---|
| EO 1.1 | STATE the five types of information provided in the title block of an engineering drawing. |
| EO 1.2 | STATE how the grid system on an engineering drawing is used to locate a piece of equipment. |
| EO 1.3 | STATE the three types of information provided in the revision block of an engineering drawing. |
| EO 1.4 | STATE the purpose of the notes and legend section of an engineering drawing. |
-

Introduction

The ability to read and understand information contained on drawings is essential to perform most engineering-related jobs. Engineering drawings are the industry's means of communicating detailed and accurate information on how to fabricate, assemble, troubleshoot, repair, and operate a piece of equipment or a system. To understand how to "read" a drawing it is necessary to be familiar with the standard conventions, rules, and basic symbols used on the various types of drawings. But before learning how to read the actual "drawing," an understanding of the information contained in the various non-drawing areas of a print is also necessary. This chapter will address the information most commonly seen in the non-drawing areas of a nuclear grade engineering type drawing. Because of the extreme variation in format, location of information, and types of information presented on drawings from vendor to vendor and site to site, all drawings will not necessarily contain the following information or format, but will usually be similar in nature.

In this handbook the terms print, drawing, and diagram are used interchangeably to denote the complete drawing. This includes the graphic portion, the title block, the grid system, the revision block, and the notes and legend. When the words print, drawing, or diagram, appear in quotes, the word is referring only to the actual graphic portion of the drawing.

Anatomy of a Drawing

A generic engineering drawing can be divided into the following five major areas or parts.

1. Title block
2. Grid system
3. Revision block
4. Notes and legends
5. Engineering drawing (graphic portion)

The information contained in the drawing itself will be covered in subsequent modules. This module will cover the non-drawing portions of a print. The first four parts listed above provide important information about the actual drawing. The ability to understand the information contained in these areas is as important as being able to read the drawing itself. Failure to understand these areas can result in improper use or the misinterpretation of the drawing.

The Title Block

The title block of a drawing, usually located on the bottom or lower right hand corner, contains all the information necessary to identify the drawing and to verify its validity. A title block is divided into several areas as illustrated by Figure 1.

First Area of the Title Block

The first area of the title block contains the drawing title, the drawing number, and lists the location, the site, or the vendor. The drawing title and the drawing number are used for identification and filing purposes. Usually the number is unique to the drawing and is comprised of a code that contains information about the drawing such as the site, system, and type of drawing. The drawing number may also contain information such as the sheet number, if the drawing is part of a series, or it may contain the revision level. Drawings are usually filed by their drawing number because the drawing title may be common to several prints or series of prints.

Second Area of the Title Block

The second area of the title block contains the signatures and approval dates, which provide information as to when and by whom the component/system was designed and when and by whom the drawing was drafted and verified for final approval. This information can be invaluable in locating further data on the system/component design or operation. These names can also help in the resolution of a discrepancy between the drawing and another source of information.

[illegible]

Figure 1 Title Block

Third Area of the Title Block

The third area of the title block is the reference block. The reference block lists other drawings that are related to the system/component, or it can list all the other drawings that are cross-referenced on the drawing, depending on the site's or vendor's conventions. The reference block can be extremely helpful in tracing down additional information on the system or component.

Other information may also be contained in the title block and will vary from site to site and vendor to vendor. Some examples are contract numbers and drawing scale.

Drawing Scale

All drawings can be classified as either drawings with scale or those not drawn to scale. Drawings without a scale usually are intended to present only functional information about the component or system. Prints drawn to scale allow the figures to be rendered accurately and precisely. Scale drawings also allow components and systems that are too large to be drawn full size to be drawn in a more convenient and easy to read size. The opposite is also true. A very small component can be scaled up, or enlarged, so that its details can be seen when drawn on paper.

Scale drawings usually present the information used to fabricate or construct a component or system. If a drawing is drawn to scale, it can be used to obtain information such as physical dimensions, tolerances, and materials that allows the fabrication or construction of the component or system. Every dimension of a component or system does not have to be stated in writing on the drawing because the user can actually measure the distance (e.g., the length of a part) from the drawing and divide or multiply by the stated scale to obtain the correct measurements.

The scale of a drawing is usually presented as a ratio and is read as illustrated in the following examples.

- | | |
|-------------|--|
| $1" = 1"$ | Read as 1 inch (on the drawing) equals 1 inch (on the actual component or system). This can also be stated as FULL SIZE in the scale block of the drawing. The measured distance on the drawing is the actual distance or size of the component. |
| $3/8" = 1'$ | Read as 3/8 inch (on the drawing) equals 1 foot (on the actual component or system). This is called 3/8 scale. For example, if a component part measures 6/8 inch on the drawing, the actual component measures 2 feet. |
| $1/2" = 1'$ | Read as 1/2 inch (on the drawing) equals 1 foot (on the actual component or system). This is called 1/2 scale. For example, if a component part measures 1-1/2 inches on the drawing the actual component measures 3 feet. |

Grid System

Because drawings tend to be large and complex, finding a specific point or piece of equipment on a drawing can be quite difficult. This is especially true when one wire or pipe run is continued on a second drawing. To help locate a specific point on a referenced print, most drawings, especially Piping and Instrument Drawings (P&ID) and electrical schematic drawings, have a grid system. The grid can consist of letters, numbers, or both that run horizontally and vertically around the drawing as illustrated on Figure 2. Like a city map, the drawing is divided into smaller blocks, each having a unique two letter or number identifier. For example, when a pipe is continued from one drawing to another, not only is the second drawing referenced on the first drawing, but so are the grid coordinates locating the continued pipe. Therefore the search for the pipe contained in the block is much easier than searching the whole drawing.

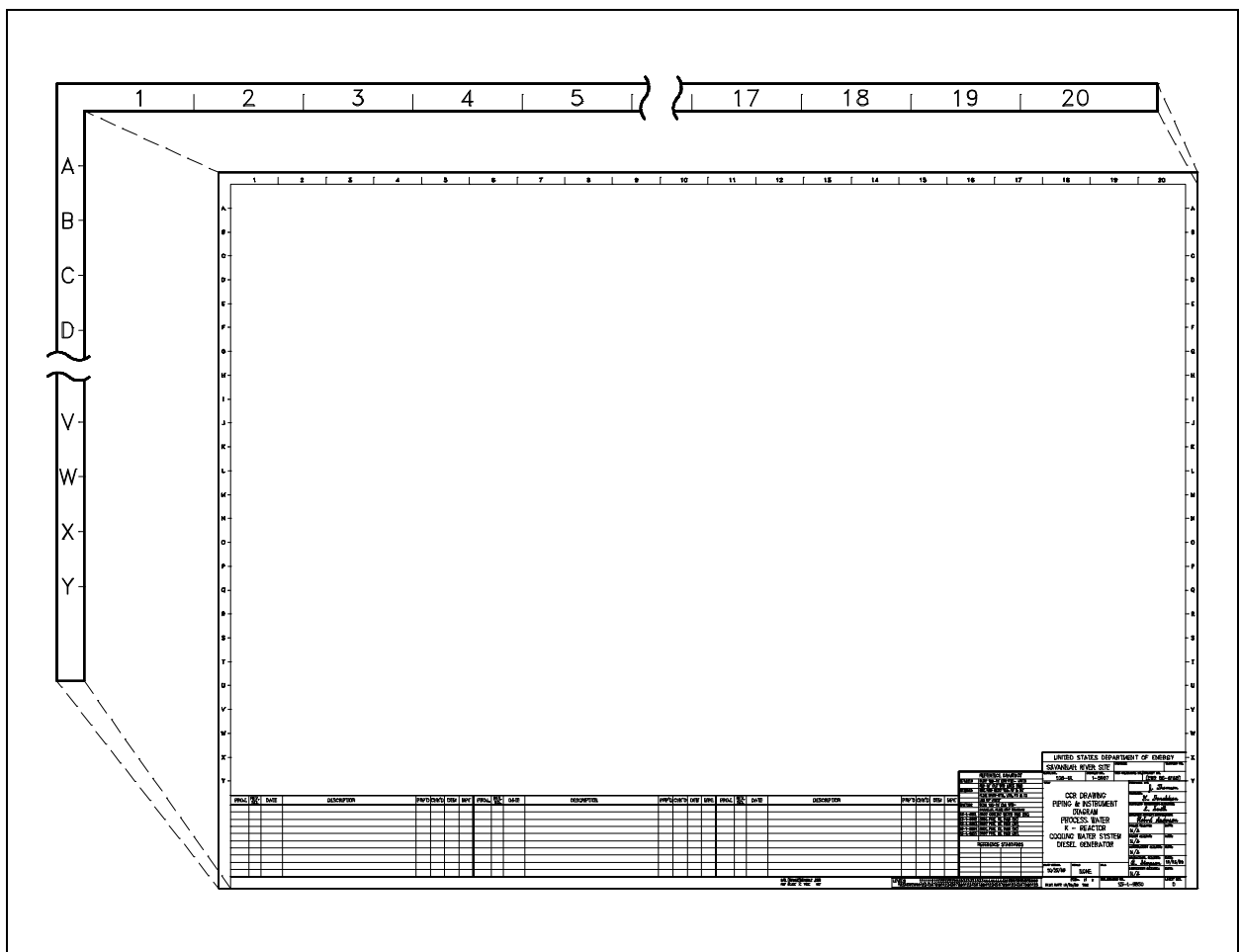


Figure 2 Example of a Grid

Changes

There are two common methods of indicating where a revision has changed a drawing that contains a system diagram. The first is the cloud method, where each change is enclosed by a hand-drawn cloud shape, as shown in Figure 4. The second method involves placing a circle (or triangle or other shape) with the revision number next to each effected portion of the drawing, as shown in Figure 4. The cloud method indicates changes from the most recent revision only, whereas the second method indicates all revisions to the drawing because all of the previous revision circles remain on the drawing.

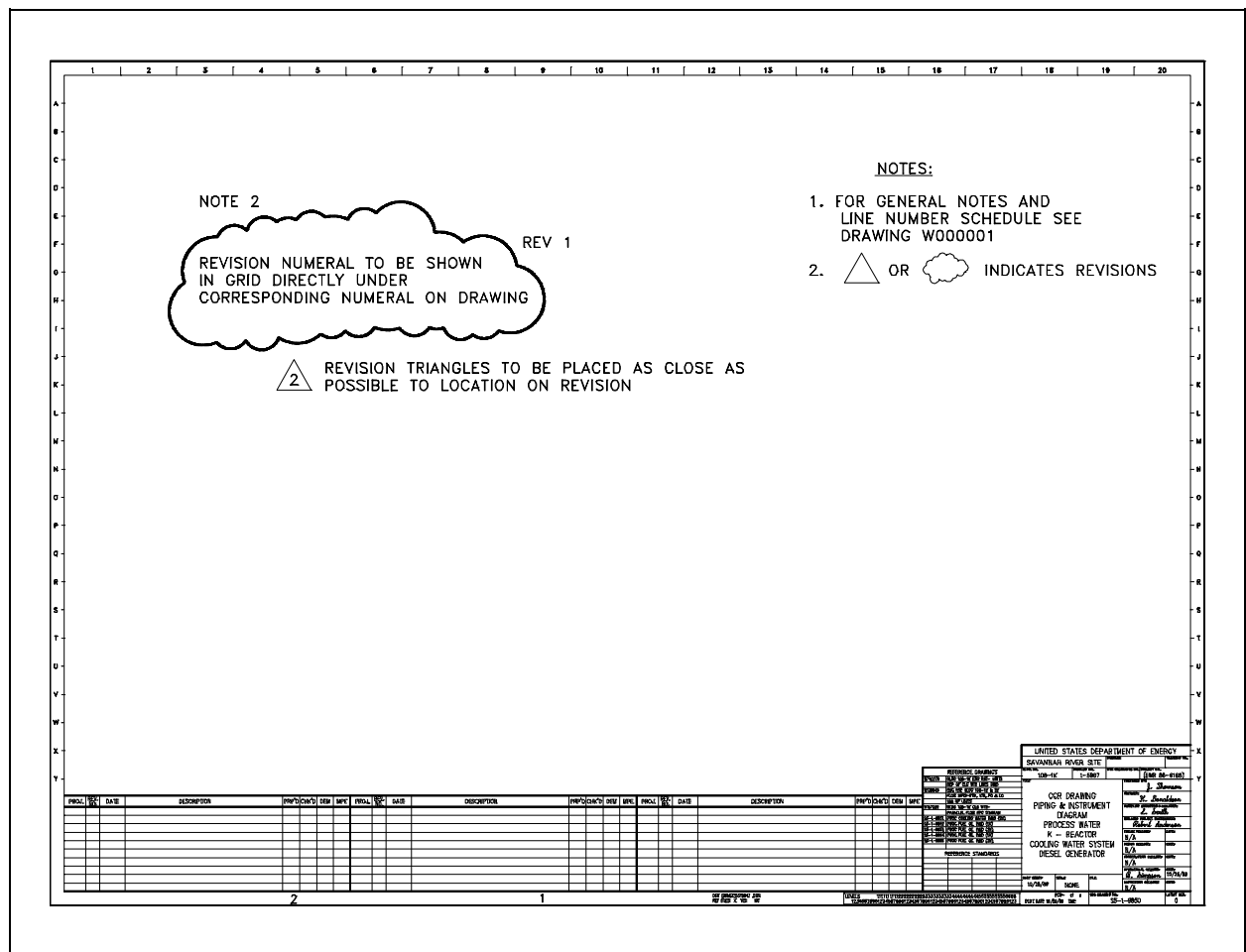


Figure 4 Methods of Denoting Changes

The revision number and revision block are especially useful in researching the evolution of a specific system or component through the comparison of the various revisions.

Notes and Legend

Drawings are comprised of symbols and lines that represent components or systems. Although a majority of the symbols and lines are self-explanatory or standard (as described in later modules), a few unique symbols and conventions must be explained for each drawing. The notes and legends section of a drawing lists and explains any special symbols and conventions used on the drawing, as illustrated on Figure 5. Also listed in the notes section is any information the designer or draftsman felt was necessary to correctly use or understand the drawing. Because of the importance of understanding all of the symbols and conventions used on a drawing, the notes and legend section must be reviewed before reading a drawing.

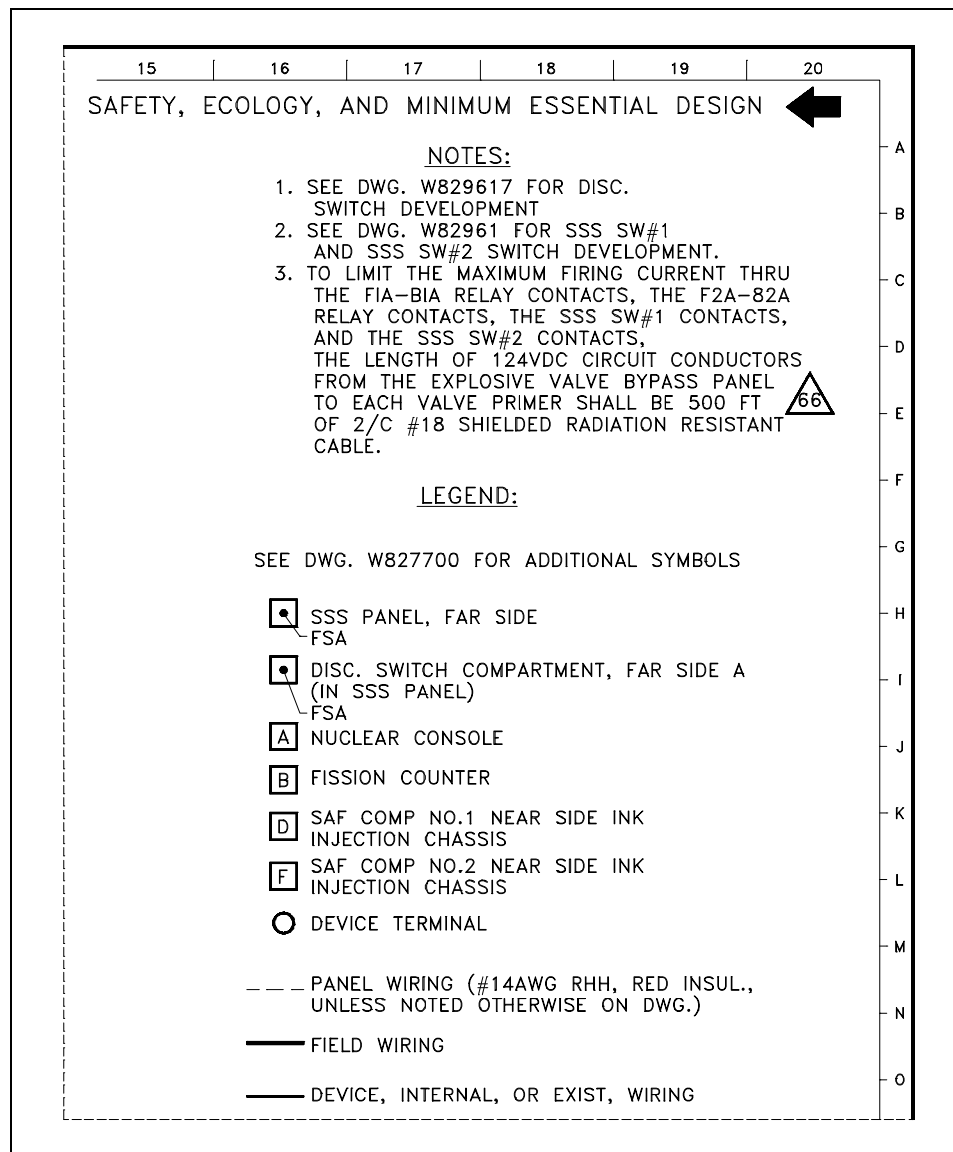


Figure 5 Notes and Legends

Summary

The important information in this chapter is summarized below.

Introduction to Print Reading Summary

- The title block of a drawing contains:
 - the drawing title
 - the drawing number
 - location, site, or vendor issuing the drawing
 - the design, review, and approval signatures
 - the reference block
- The grid system of a drawing allows information to be more easily identified using the coordinates provided by the grid. The coordinate letters and/or numbers break down the drawing into smaller blocks.
- The revision block of a drawing provides the revision number, a title or summary of the revision, and the date of the revision, for each revision.
- The notes and legend section of a drawing provides explanations of special symbols or conventions used on the drawing and any additional information the designer or draftsman felt was necessary to understand the drawing.

INTRODUCTION TO THE TYPES OF DRAWINGS, VIEWS, AND PERSPECTIVES

To read a drawing correctly, the user must have a basic understanding of the various categories of drawings and the views and perspectives in which each drawing can be presented.

EO 1.5 LIST the five drawing categories used on engineering drawings.

Categories of Drawings

The previous chapter reviewed the non-drawing portions of a print. This chapter will introduce the five common categories of drawings. They are 1) piping and instrument drawings (P&IDs), 2) electrical single lines and schematics, 3) electronic diagrams and schematics, 4) logic diagrams and prints, and 5) fabrication, construction, and architectural drawings.

Piping and Instrument Drawings (P&IDs)

P&IDs are usually designed to present functional information about a system or component. Examples are piping layout, flowpaths, pumps, valves, instruments, signal modifiers, and controllers, as illustrated in Figure 6.

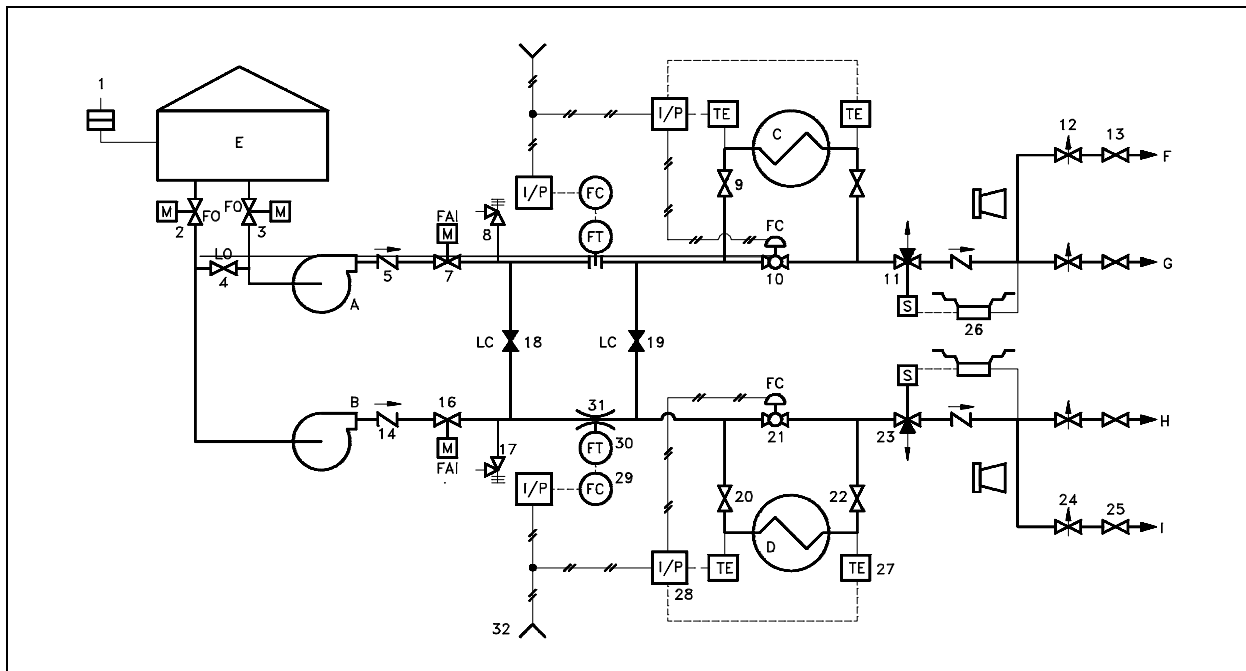


Figure 6 Example P&ID

As a rule P&IDs do not have a drawing scale and present only the relationship or sequence between components. Just because two pieces of equipment are drawn next to each other does not indicate that in the plant the equipment is even in the same building; it is just the next part or piece of the system. These drawings only present information on how a system functions, not the actual physical relationships.

Because P&IDs provide the most concise format for how a system should function, they are used extensively in the operation, repair, and modification of the plant.

Electrical Single Lines and Schematics

Electrical single lines and schematics are designed to present functional information about the electrical design of a system or component. They provide the same types of information about electrical systems that P&IDs provide for piping and instrument systems. Like P&IDs, electrical prints are not usually drawn to scale. Examples of typical single lines are site or building power distribution, system power distribution, and motor control centers. Figure 7 is an example of an electrical single line.

Electrical schematics provide a more detailed level of information about an electrical system or component than the single lines. Electrical schematic drawings present information such as the individual relays, relay contacts, fuses, motors, lights, and instrument sensors. Examples of typical schematics are valve actuating circuits, motor start circuits, and breaker circuits.

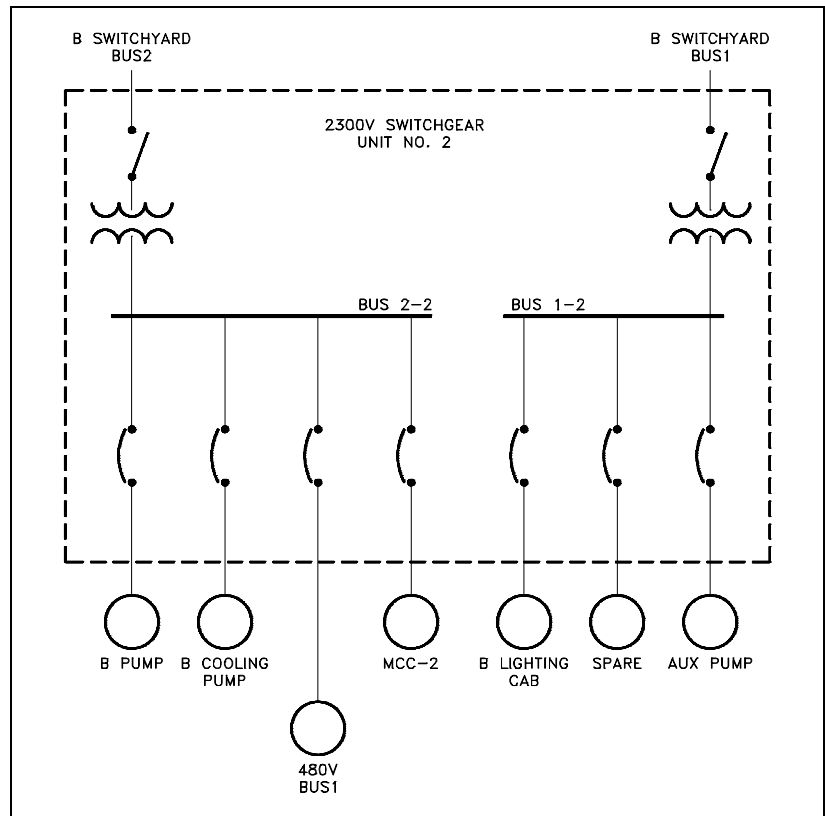


Figure 7 Example of a Single Line

Figure 8 is an example of a motor start circuit schematic. Electrical single lines and schematics provide the most concise format for depicting how electrical systems should function, and are used extensively in the operation, repair, and modification of the plant.

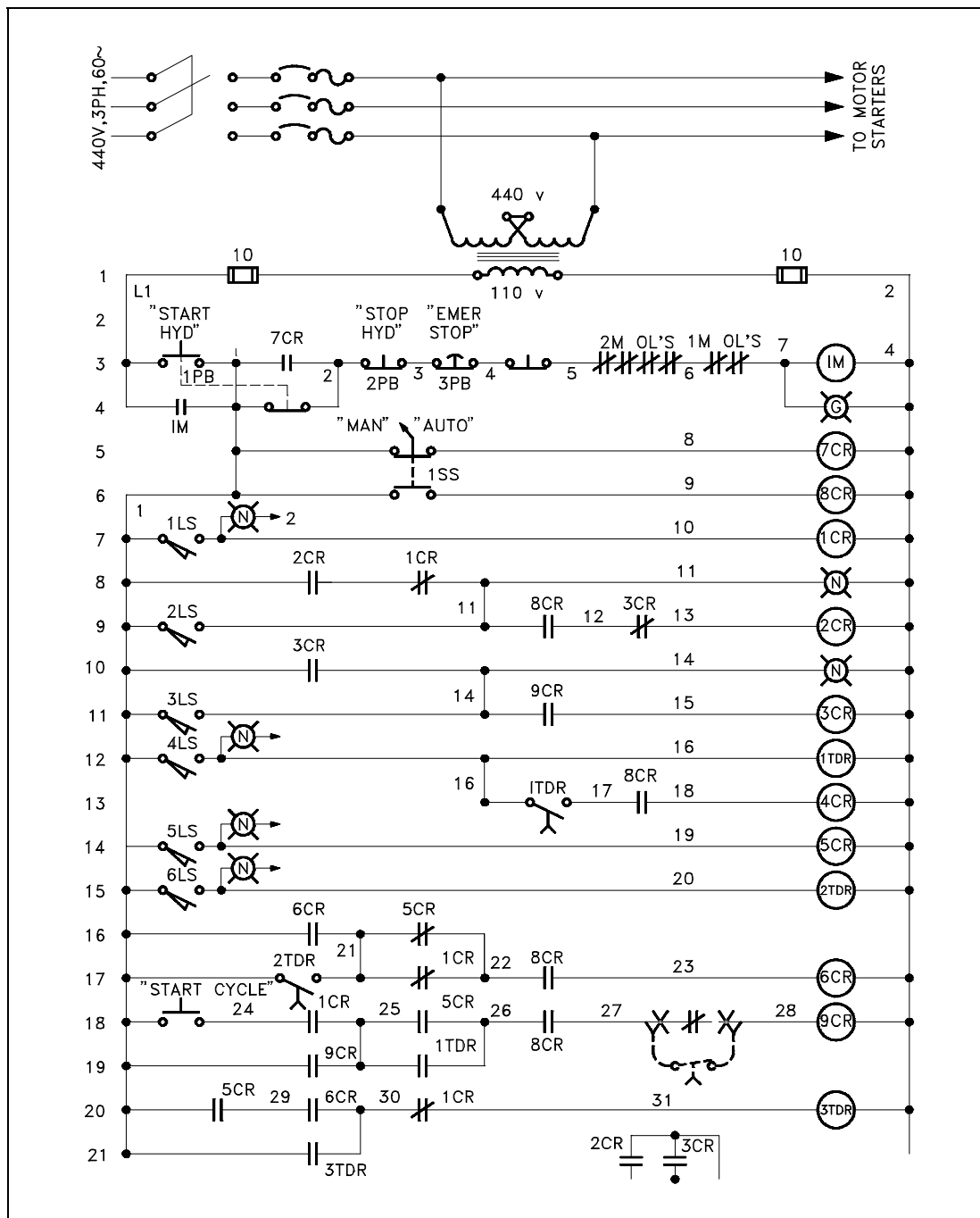


Figure 8 Example of a Schematic

Electronic Diagrams and Schematics

Electronic diagrams and schematics are designed to present information about the individual components (resistors, transistors, and capacitors) used in a circuit, as illustrated in Figure 9. These drawings are usually used by circuit designers and electronics repair personnel.

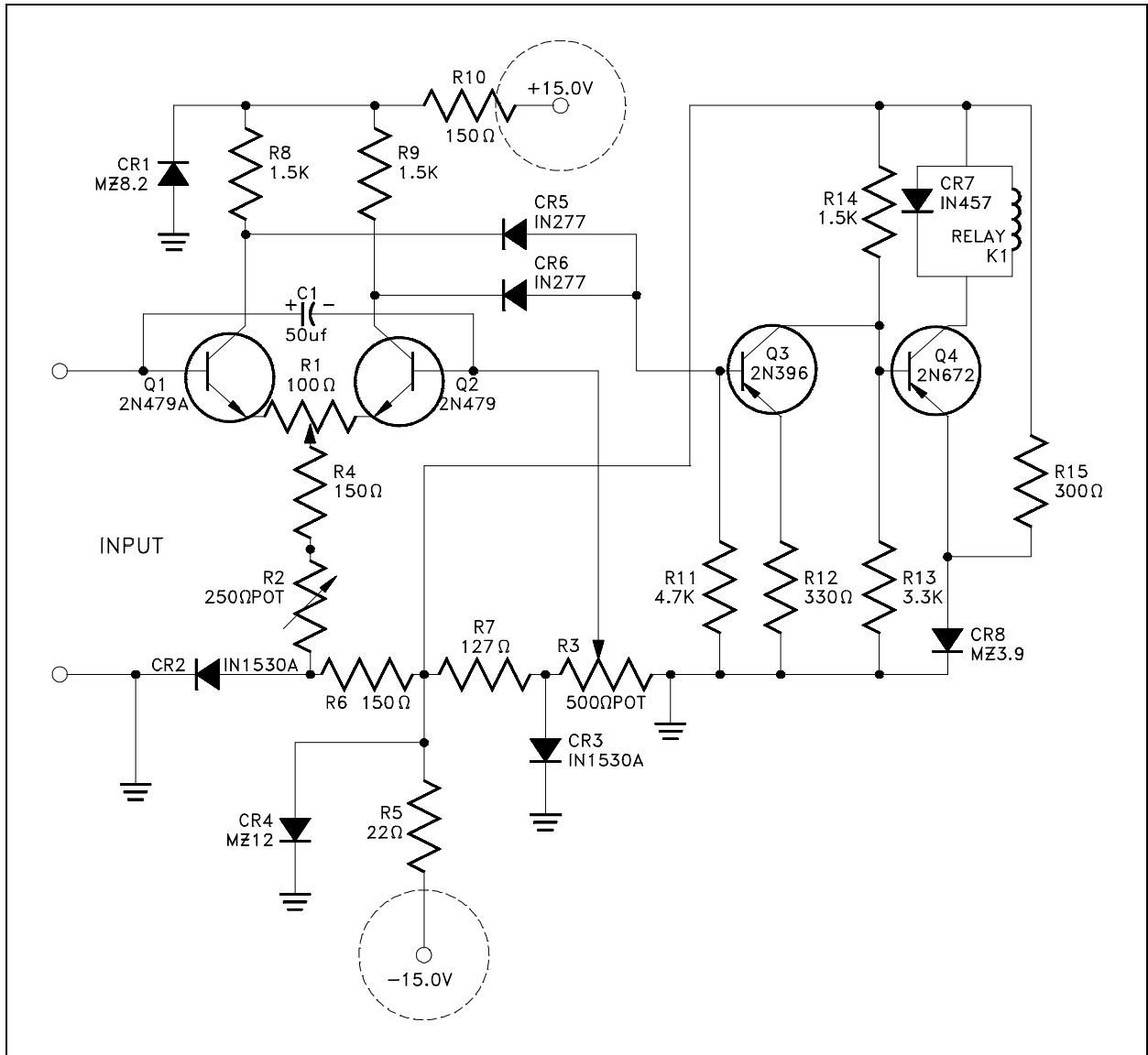


Figure 9 Example of an Electronic Diagram

Logic Diagrams and Prints

Logic diagrams and prints can be used to depict several types of information. The most common use is to provide a simplified functional representation of an electrical circuit, as illustrated in Figure 10. For example, it is easier and faster to figure out how a valve functions and responds to various inputs signals by representing a valve circuit using logic symbols, than by using the electrical schematic with its complex relays and contacts. These drawings do not replace schematics, but they are easier to use for certain applications.

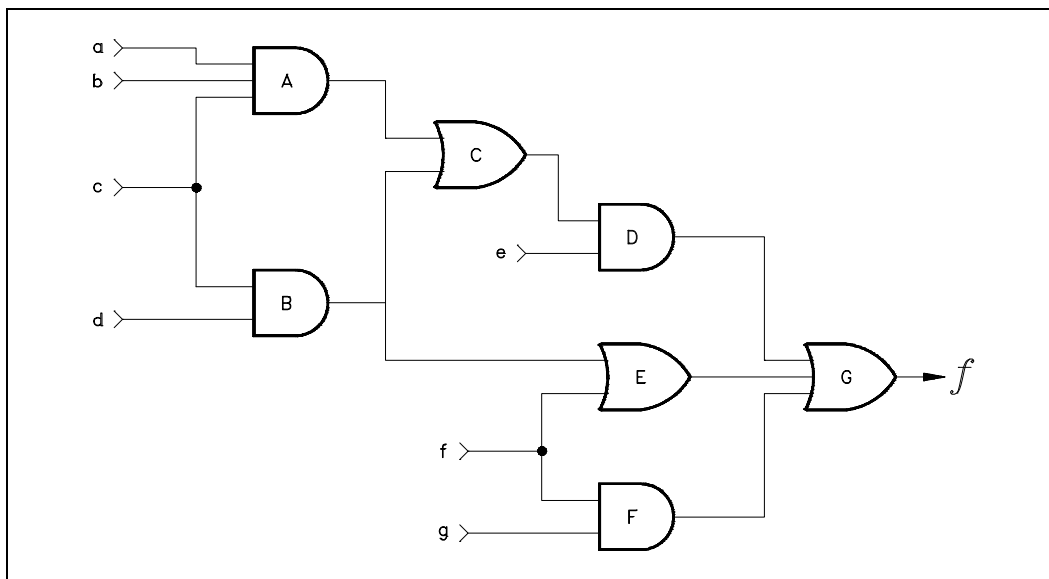


Figure 10 Example of a Logic Print

Fabrication, Construction, and Architectural Drawings

Fabrication, construction, and architectural drawings are designed to present the detailed information required to construct or fabricate a part, system, or structure. These three types of drawings differ only in their application as opposed to any real differences in the drawings themselves. Construction drawings, commonly referred to as "blueprint" drawings, present the detailed information required to assemble a structure on site. Architectural drawings present information about the conceptual design of the building or structure. Examples are house plans, building elevations (outside view of each side of a structure), equipment installation drawings, foundation drawings, and equipment assembly drawings.

Fabrication drawings, as shown in Figure 11, are similar to construction and architectural drawing but are usually found in machine shops and provide the necessary detailed information for a craftsman to fabricate a part. All three types of drawings, fabrication, construction, and architectural, are usually drawn to scale.

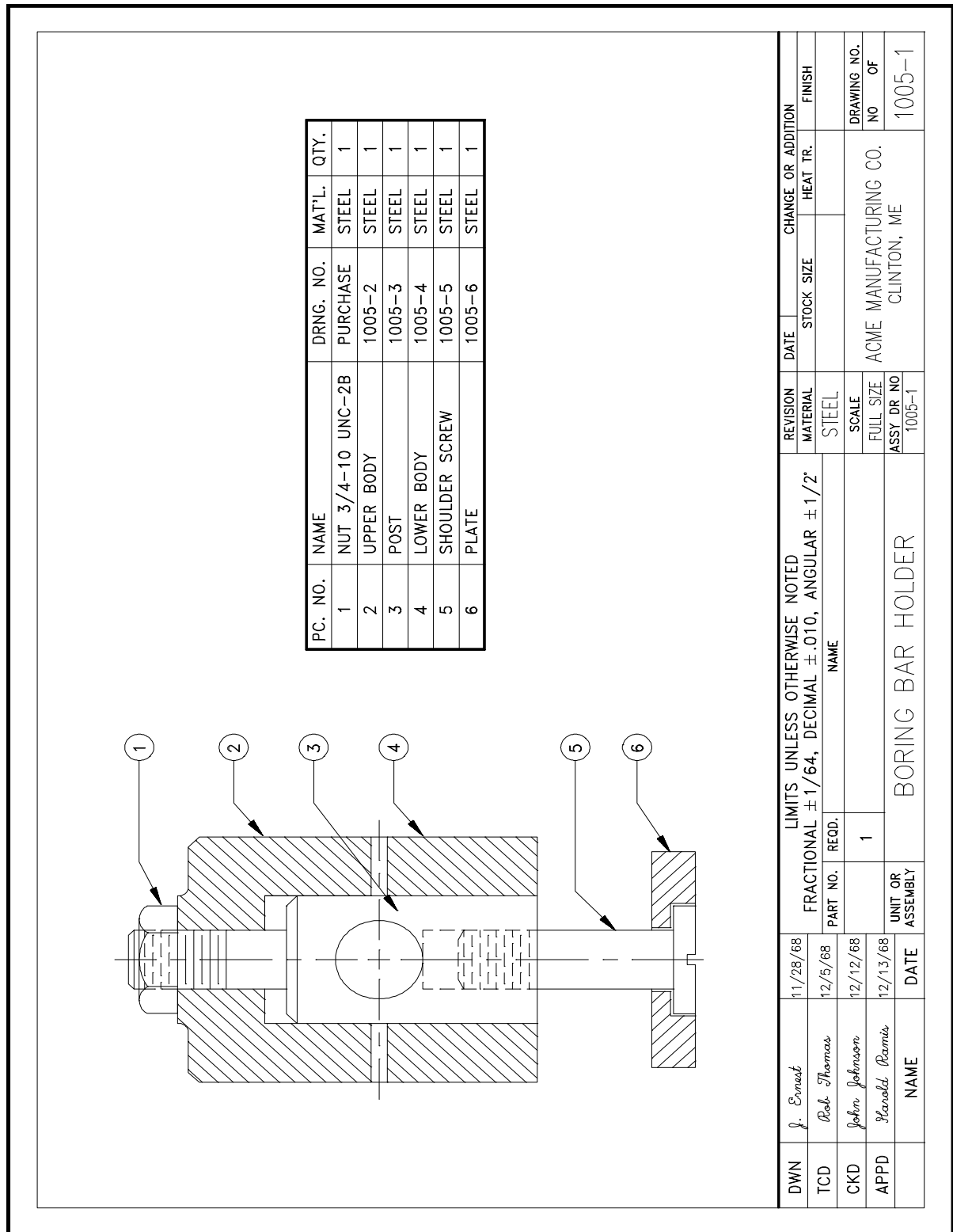


Figure 11 Example of a Fabrication Drawing

Drawing Format

P&IDs, fabrication, construction, and architectural drawings can be presented using one of several different formats. The standard formats are single line, pictorial or double line, and cutaway. Each format provides specific information about a component or system.

Single Line Drawings

The single line format is most commonly used in P&IDs. Figure 12 is an example of a single line P&ID. The single line format represents all piping, regardless of size, as single line. All system equipment is represented by simple standard symbols (covered in later modules). By simplifying piping and equipment, single lines allow the system's equipment and instrumentation relationships to be clearly understood by the reader.

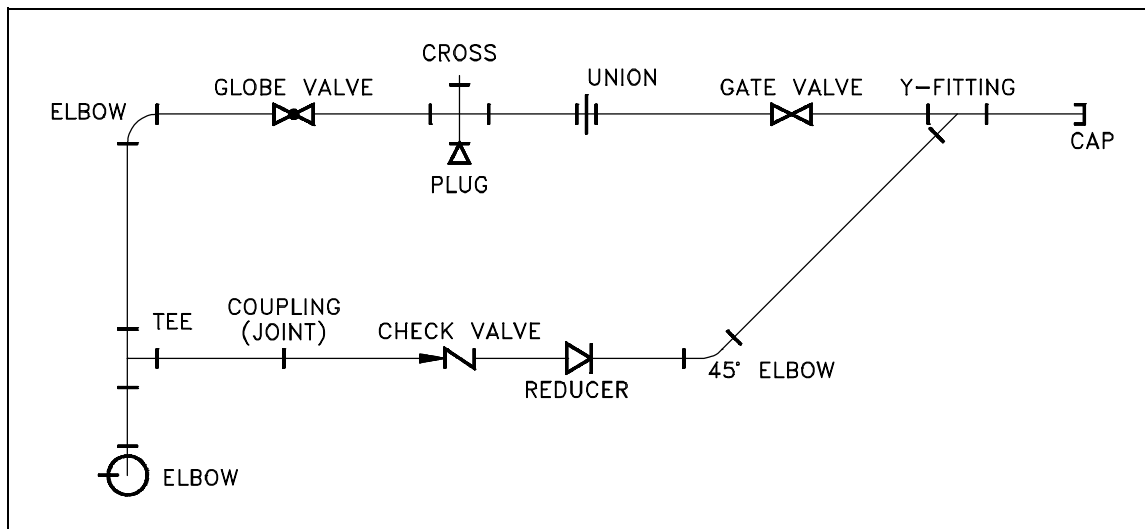


Figure 12 Example of a Single Line P&ID

Pictorial or Double Line Drawings

Pictorial or double line drawings present the same type information as a single line, but the equipment is represented as if it had been photographed. Figure 13 provides an example illustration of a pictorial drawing. This format is rarely used since it requires much more effort to produce than a single line drawing and does not present any more information as to how the system functions. Compare the pictorial illustration, Figure 13, to the single line of the same system shown in Figure 12. Pictorial or double line drawings are often used in advertising and training material.

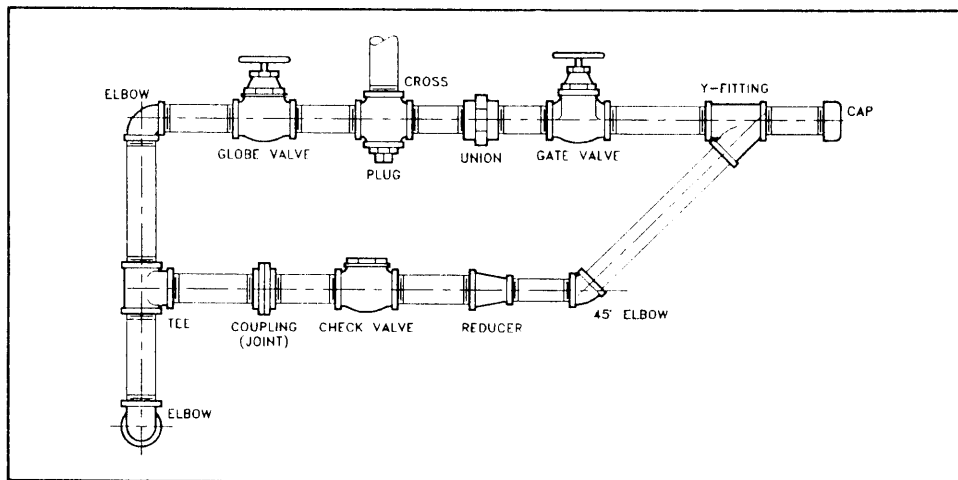


Figure 13 Example Pictorial

Assembly Drawings

Assembly drawing are a special application of pictorial drawings that are common in the engineering field. As seen in Figure 14, an assembly drawing is a pictorial view of the object with all the components shown as they go together. This type pictorial is usually found in vendor manuals and is used for parts identification and general information relative to the assembly of the component.

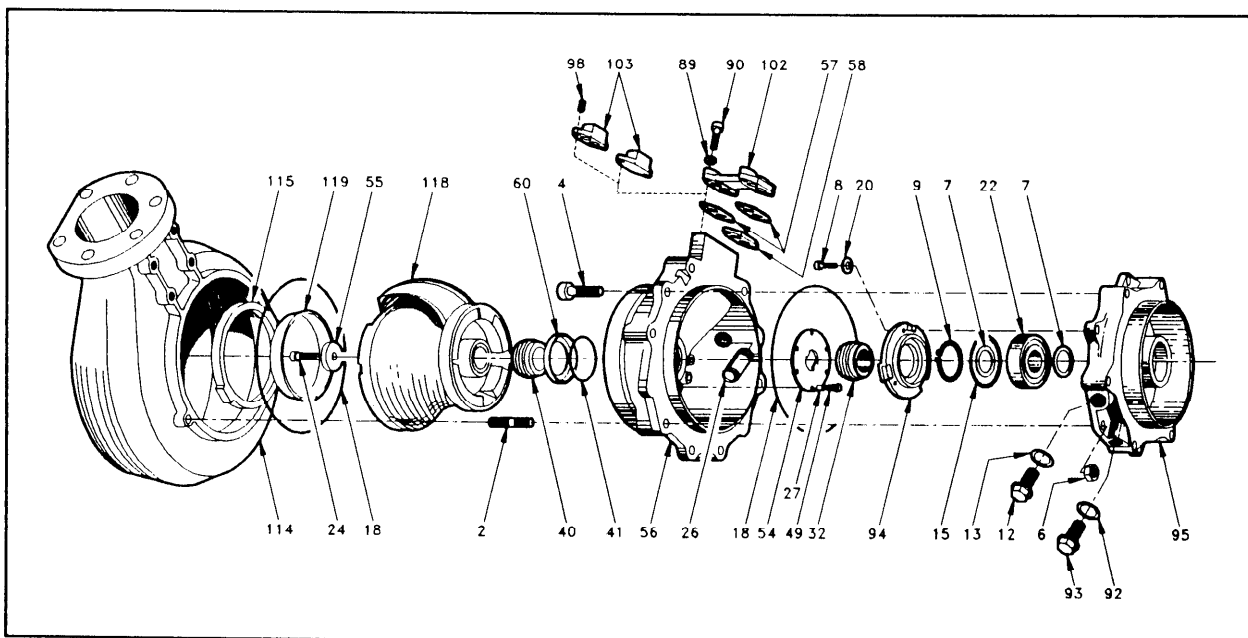


Figure 14 Example of an Assembly Drawing

Cutaway Drawings

A cutaway drawing is another special type of pictorial drawing. In a cutaway, as the name implies, the component or system has a portion cut away to reveal the internal parts of the component or system. Figure 15 is an illustration of a cutaway. This type of drawing is extremely helpful in the maintenance and training areas where the way internal parts are assembled is important.

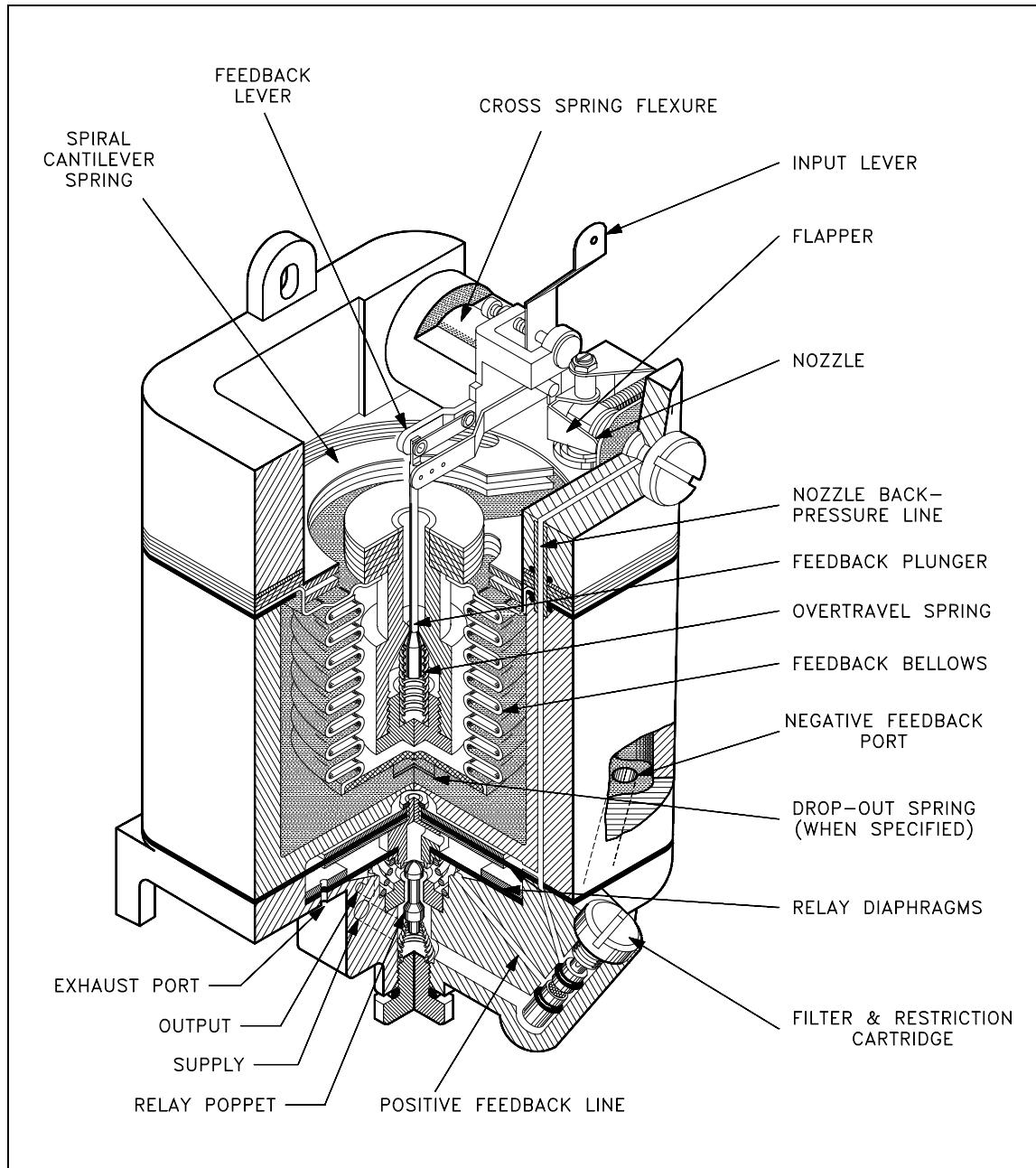


Figure 15 Example of a Cutaway

Views and Perspectives

In addition to the different drawing formats, there are different views or perspectives in which the formats can be drawn. The most commonly used are the orthographic projection and the isometric projection.

Orthographic Projections

Orthographic projection is widely used for fabrication and construction type drawings, as shown in Figure 16. Orthographic projections present the component or system through the use of three views, These are a top view, a side view, and a front view. Other views, such as a bottom view, are used to more fully depict the component or system when necessary.

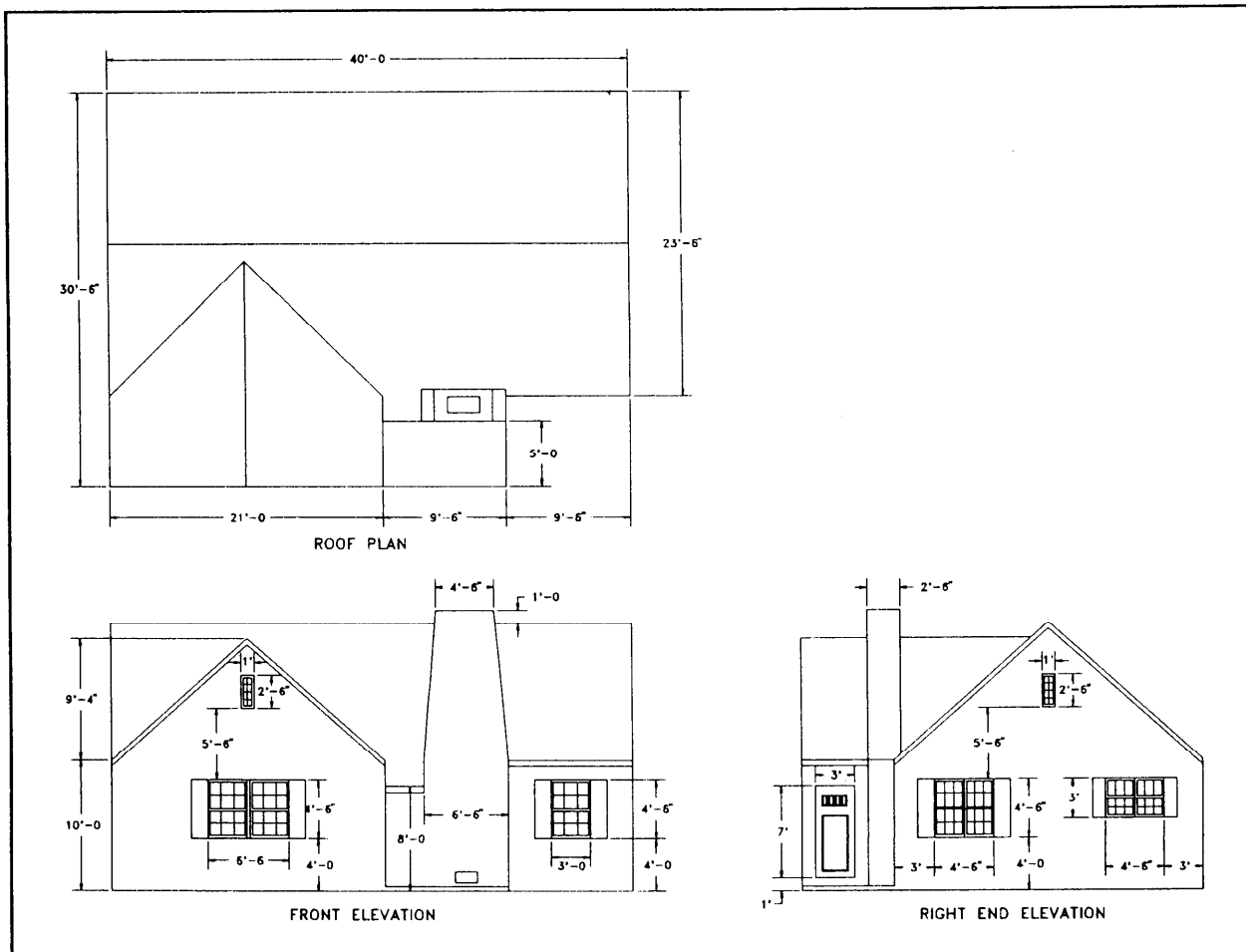


Figure 16 Example Orthographic Projection

Figure 17 shows how each of the three views is obtained. The orthographic projection is typically drawn to scale and shows all components in their proper relationships to each other. The three views, when provided with dimensions and a drawing scale, contain information that is necessary to fabricate or construct the component or system.

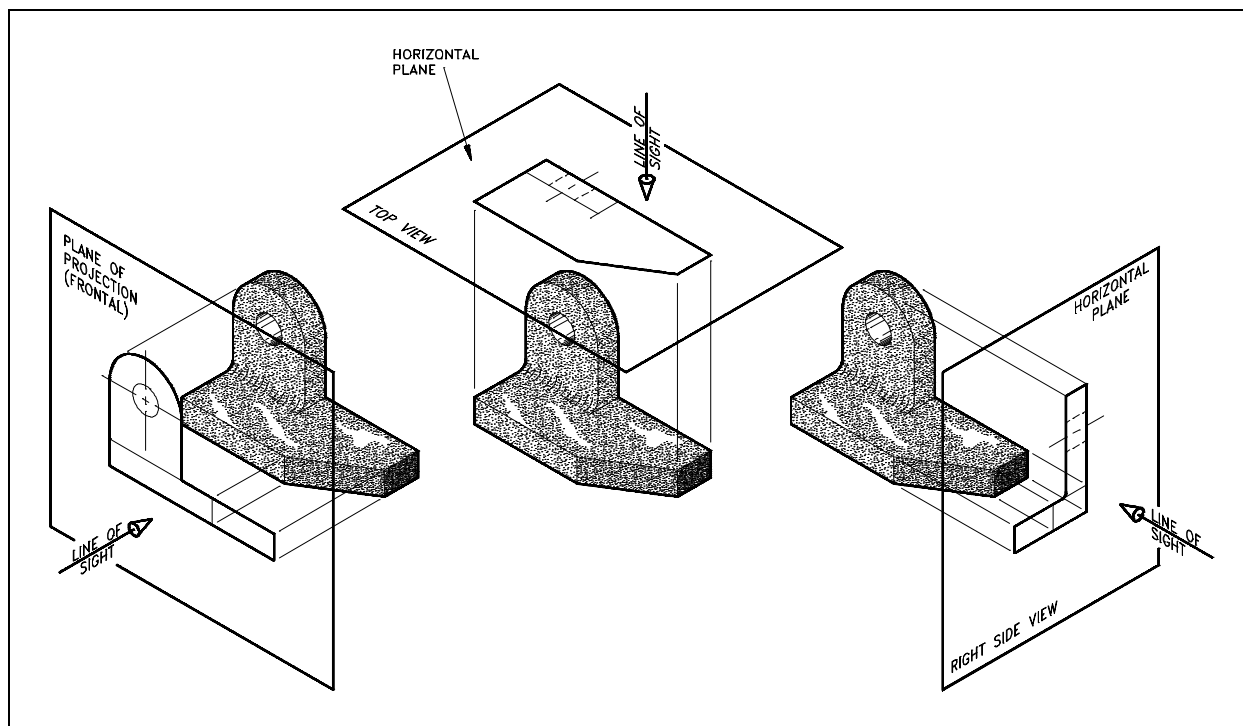


Figure 17 Orthographic Projections

Isometric Projection

The isometric projection presents a single view of the component or system. The view is commonly from above and at an angle of 30°. This provides a more realistic three-dimensional view. As shown on Figure 18, this view makes it easier to see how the system looks and how its various portions or parts are related to one another. Isometric projections may or may not be drawn to a scale.

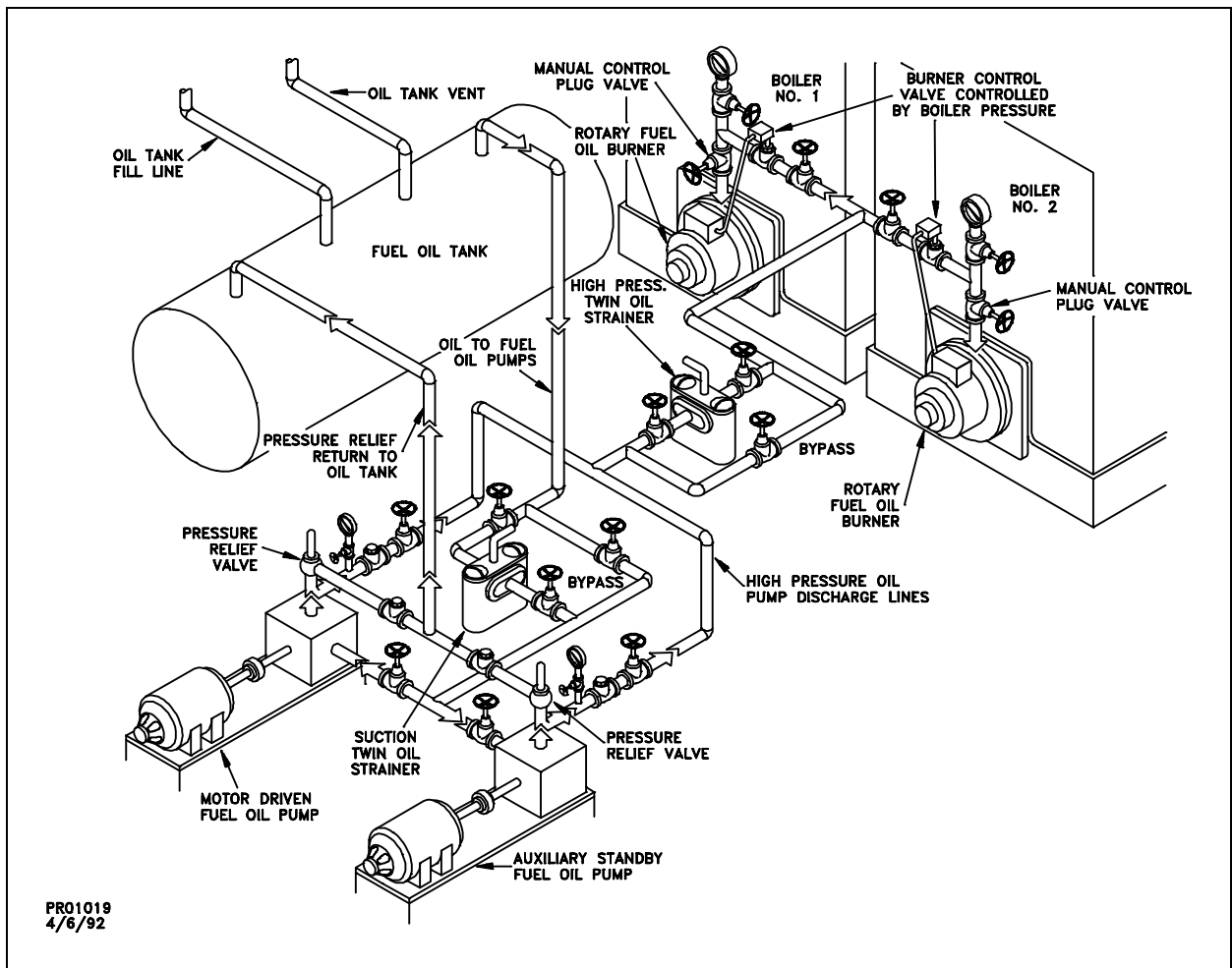


Figure 18 Example of an Isometric

Summary

The important information in this chapter is summarized below.

Drawing Types, Views, and Perspectives Summary

- The five engineering drawing categories are:
 - P&IDs
 - Electrical single lines and schematics
 - Electronic diagrams and schematics
 - Logic diagrams and prints
 - Fabrication, construction, and architectural drawings

Department of Energy
Fundamentals Handbook

**ENGINEERING SYMBOLOGY, PRINTS,
AND DRAWINGS**
Module 2
**Engineering Fluid
Diagrams and Prints**

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TERMINAL OBJECTIVE

- 1.0 Given an engineering print, **READ** and **INTERPRET** facility engineering Piping and Instrument Drawings.

ENABLING OBJECTIVES

- 1.1 **IDENTIFY** the symbols used on engineering P&IDs for the following types of valves:

- | | |
|---------------------|----------------------------|
| a. Globe valve | g. Relief valve |
| b. Gate valve | h. Rupture disk |
| c. Ball valve | i. Three-way valve |
| d. Check valve | j. Four-way valve |
| e. Stop check valve | k. Throttle (needle) valve |
| f. Butterfly valve | l. Pressure regulator |

- 1.2 **IDENTIFY** the symbols used on engineering P&IDs for the following types of valve operators:

- a. Diaphragm valve operator
- b. Motor valve operator
- c. Solenoid valve operator
- d. Piston (hydraulic) valve operator
- e. Hand (manual) valve operator
- f. Reach-rod valve operator

- 1.3 **IDENTIFY** the symbols used on engineering P&IDs for educators and ejectors.

- 1.4 **IDENTIFY** the symbols used on engineering P&IDs for the following lines:

- a. Process
- b. Pneumatic
- c. Hydraulic
- d. Inert gas
- e. Instrument signal (electrical)
- f. Instrument capillary
- g. Electrical

ENABLING OBJECTIVES (cont.)

- 1.5 **IDENTIFY** the symbols used on engineering P&IDs for the following basic types of instrumentation:
- a. Differential pressure cell
 - b. Temperature element
 - c. Venturi
 - d. Orifice
 - e. Rotometer
 - f. Conductivity or salinity cell
 - g. Radiation detector
- 1.6 **IDENTIFY** the symbols used on engineering P&IDs to denote the location, either local or board mounted, of instruments, indicators, and controllers.
- 1.7 **IDENTIFY** the symbols used on engineering P&IDs for the following types of instrument signal controllers and modifiers:
- a. Proportional
 - b. Proportional-integral
 - c. Proportional-integral-differential
 - d. Square root extractors
- 1.8 **IDENTIFY** the symbols used on engineering P&IDs for the following types of system components:
- a. Centrifugal pumps
 - b. Positive displacement pumps
 - c. Heat exchangers
 - d. Compressors
 - e. Fans
 - f. Tanks
 - g. Filters/strainers

ENABLING OBJECTIVES (cont.)

- 1.9 **STATE** how the following valve conditions are depicted on an engineering P&ID:
- a. Open valve
 - b. Closed valve
 - c. Throttled valve
 - d. Combination valves (3- or 4-way valve)
 - e. Locked-closed valve
 - f. Locked-open valve
 - g. Fail-open valve
 - h. Fail-closed valve
 - i. Fail-as-is valve
- 1.10 Given an engineering P&ID, **IDENTIFY** components and **DETERMINE** the flowpath(s) for a given valve lineup.
- 1.11 **IDENTIFY** the symbols used on engineering fluid power drawings for the following components:
- a. Pump
 - b. Compressor
 - c. Reservoir
 - d. Actuators
 - e. Piping and piping junctions
 - f. Valves
- 1.12 Given a fluid power type drawing, **DETERMINE** the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

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ENGINEERING FLUIDS DIAGRAMS AND PRINTS

To read and understand engineering fluid diagrams and prints, usually referred to as P&IDs, an individual must be familiar with the basic symbols.

EO 1.1 IDENTIFY the symbols used on engineering P&IDs for the following types of valves:

- | | |
|----------------------------|-----------------------------------|
| a. Globe valve | g. Relief valve |
| b. Gate valve | h. Rupture disk |
| c. Ball valve | i. Three-way valve |
| d. Check valve | j. Four-way valve |
| e. Stop check valve | k. Throttle (needle) valve |
| f. Butterfly valve | l. Pressure regulator |

EO 1.2 IDENTIFY the symbols used on engineering P&IDs for the following types of valve operators:

- a. Diaphragm valve operator**
- b. Motor valve operator**
- c. Solenoid valve operator**
- d. Piston (hydraulic) valve operator**
- e. Hand (manual) valve operator**
- f. Reach rod valve operator**

EO 1.3 IDENTIFY the symbols used on engineering P&IDs for educators and ejectors.

EO 1.4 IDENTIFY the symbols used on engineering P&IDs for the following lines:

- | | |
|---------------------|--|
| a. Process | e. Instrument signal (electrical) |
| b. Pneumatic | f. Instrument capillary |
| c. Hydraulic | g. Electrical |
| d. Inert gas | |

EO 1.5 IDENTIFY the symbols used on engineering P&IDs for the following basic types of instrumentation:

- | | |
|--------------------------------------|---|
| a. Differential pressure cell | e. Rotometer |
| b. Temperature element | f. Conductivity or salinity cell |
| c. Venturi | g. Radiation detector |
| d. Orifice | |

EO 1.6 IDENTIFY the symbols used on engineering P&IDs to denote the location, either local or board mounted, of instruments, indicators, and controllers.

EO 1.7 IDENTIFY the symbols used on engineering P&IDs for the following types of instrument signal modifiers:

- a. Proportional**
- b. Proportional-integral**
- c. Proportional-integral-differential**
- d. Square root extractors**

EO 1.8 IDENTIFY the symbols used on engineering P&IDs for the following types of system components:

- | | |
|---------------------------------------|-----------------------------|
| a. Centrifugal pumps | e. Fans |
| b. Positive displacement pumps | f. Tanks |
| c. Heat exchangers | g. Filters/strainers |
| d. Compressors | |
-

Symbology

To read and interpret piping and instrument drawings (P&IDs), the reader must learn the meaning of the symbols. This chapter discusses the common symbols that are used to depict fluid system components. When the symbology is mastered, the reader will be able to interpret most P&IDs.

The reader should note that this chapter is only representative of fluid system symbology, rather than being all-inclusive. The symbols presented herein are those most commonly used in engineering P&IDs. The reader may expand his or her knowledge by obtaining and studying the appropriate drafting standards used at his or her facility.

Valve Symbols

Valves are used to control the direction, flow rate, and pressure of fluids. Figure 1 shows the symbols that depict the major valve types.

It should be noted that globe and gate valves will often be depicted by the same valve symbol. In such cases, information concerning the valve type may be conveyed by the component identification number or by the notes and legend section of the drawing; however, in many instances even that may not hold true.

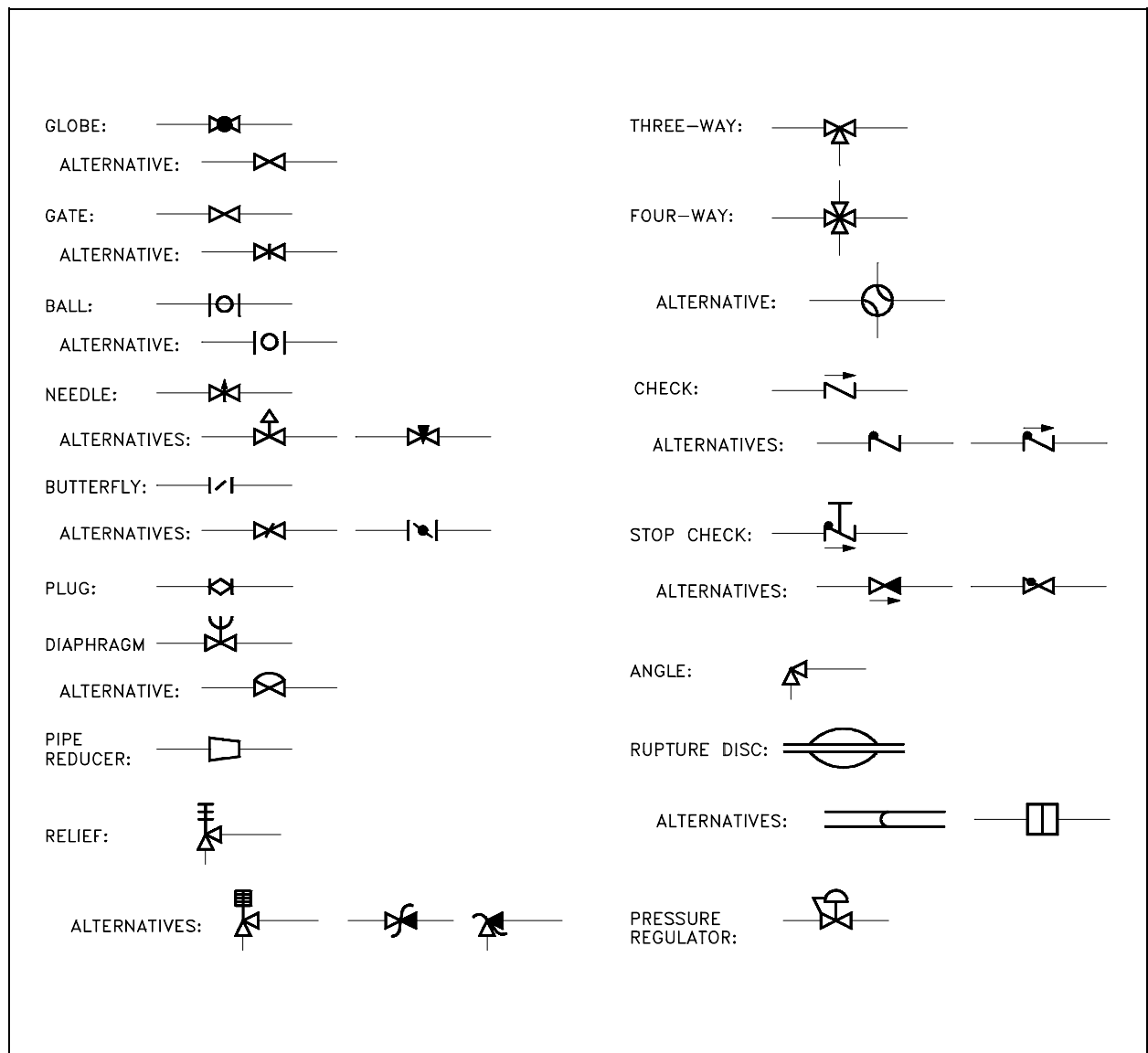


Figure 1 Valve Symbols

Valve Actuators

Some valves are provided with actuators to allow remote operation, to increase mechanical advantage, or both. Figure 2 shows the symbols for the common valve actuators. Note that although each is shown attached to a gate valve, an actuator can be attached to any type of valve body. If no actuator is shown on a valve symbol, it may be assumed the valve is equipped only with a handwheel for manual operation.

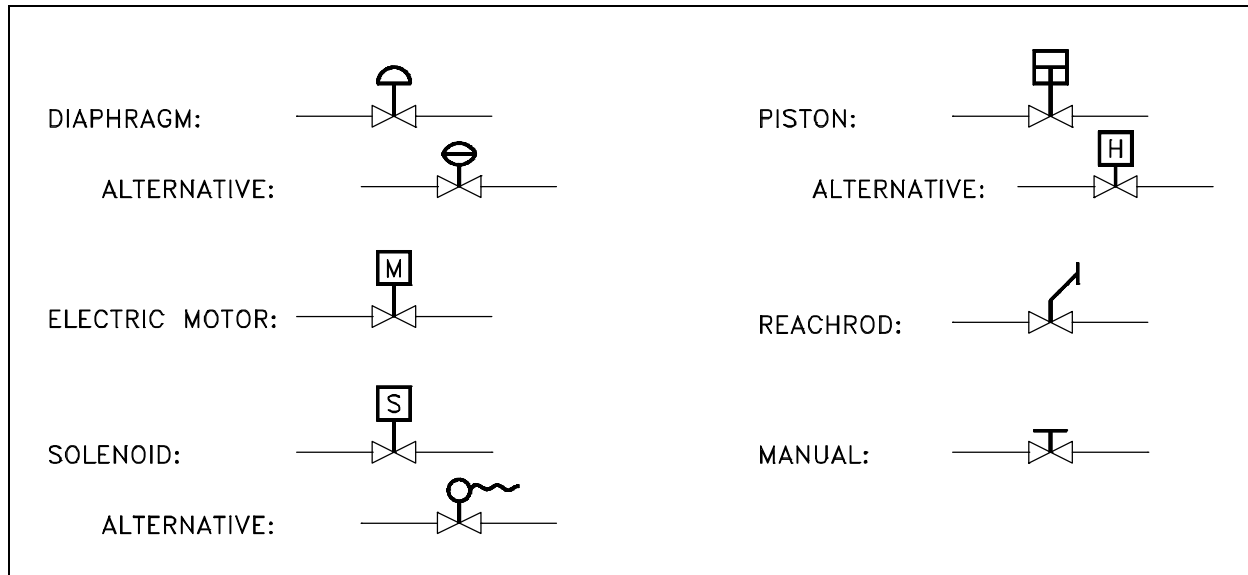


Figure 2 Valve Actuator Symbols

The combination of a valve and an actuator is commonly called a control valve. Control valves are symbolized by combining the appropriate valve symbol and actuator symbol, as illustrated in Figure 2. Control valves can be configured in many different ways. The most commonly found configurations are to manually control the actuator from a remote operating station, to automatically control the actuator from an instrument, or both.

In many cases, remote control of a valve is accomplished by using an intermediate, small control valve to operate the actuator of the process control valve. The intermediate control valve is placed in the line supplying motive force to the process control valve, as shown in Figure 3. In this example, air to the process air-operated control valve is controlled by the solenoid-operated, 3-way valve in the air supply line. The 3-way valve may supply air to the control valve's diaphragm or vent the diaphragm to the atmosphere.

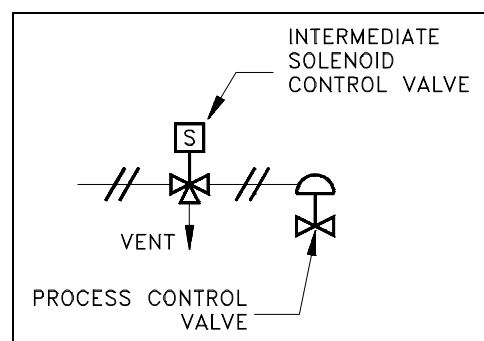


Figure 3 Remotely Controlled Valve

Note that the symbols alone in Figure 3 do not provide the reader with enough information to determine whether applying air pressure to the diaphragm opens or closes the process control valve, or whether energizing the solenoid pressurizes or vents the diaphragm. Further, Figure 3 is incomplete in that it does not show the electrical portion of the valve control system nor does it identify the source of the motive force (compressed air). Although Figure 3 informs the reader of the types of mechanical components in the control system and how they interconnect, it does not provide enough information to determine how those components react to a control signal.

Control valves operated by an instrument signal are symbolized in the same manner as those shown previously, except the output of the controlling instrument goes to the valve actuator. Figure 4 shows a level instrument (designated "LC") that controls the level in the tank by positioning an air-operated diaphragm control valve. Again, note that Figure 4 does not contain enough information to enable the reader to determine how the control valve responds to a change in level.

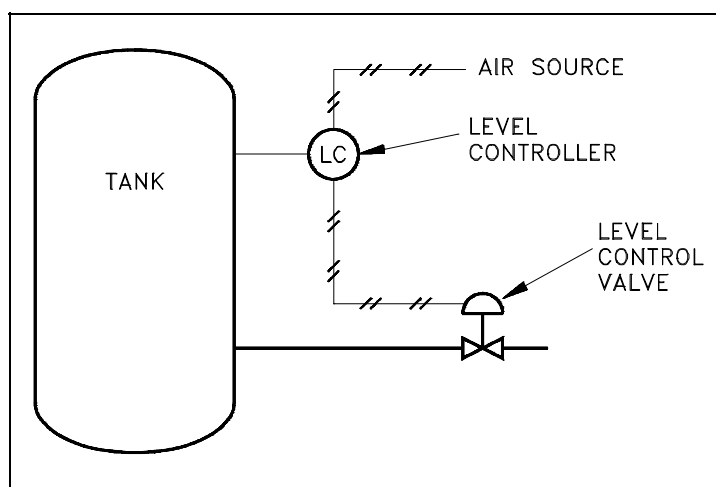


Figure 4 Level Control Valve

An additional aspect of some control valves is a valve positioner, which allows more precise control of the valve. This is especially useful when instrument signals are used to control the valve. An example of a valve positioner is a set of limit switches operated by the motion of the valve. A positioner is symbolized by a square box on the stem of the control valve actuator. The positioner may have lines attached for motive force, instrument signals, or both. Figure 5 shows two examples of valves equipped with positioners. Note that, although these examples are more detailed than those of Figure 3 and Figure 4, the reader still does not have sufficient information to fully determine response of the control valve to a change in control signal.

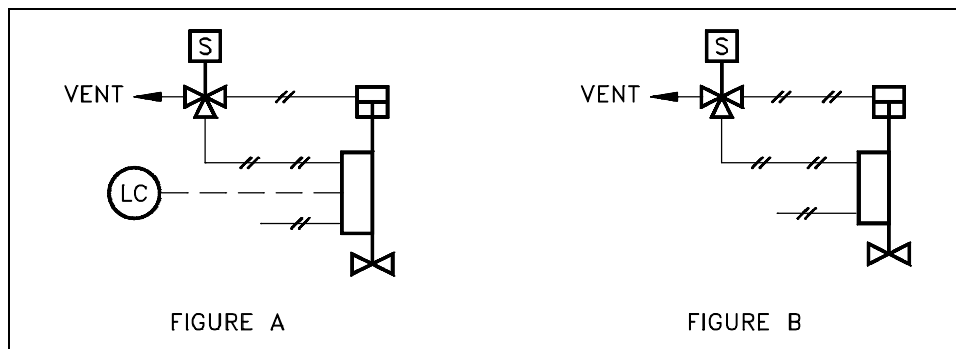


Figure 5 Control Valves with Valve Positioners

In Example A of Figure 5, the reader can reasonably assume that opening of the control valve is in some way proportional to the level it controls and that the solenoid valve provides an override of the automatic control signals. However, the reader cannot ascertain whether it opens or closes the control valve. Also, the reader cannot determine in which direction the valve moves in response to a change in the control parameter. In Example B of Figure 5, the reader can make the same general assumptions as in Example A, except the control signal is unknown. Without additional information, the reader can only assume the air supply provides both the control signal and motive force for positioning the control valve. Even when valves are equipped with positioners, the positioner symbol may appear only on detailed system diagrams. Larger, overall system diagrams usually do not show this much detail and may only show the examples of Figure 5 as air-operated valves with no special features.

Control Valve Designations

A control valve may serve any number of functions within a fluid system. To differentiate between valve uses, a balloon labeling system is used to identify the function of a control valve, as shown in Figure 6. The common convention is that the first letter used in the valve designator indicates the parameter to be controlled by the valve. For example:

- F = flow
- T = temperature
- L = level
- P = pressure
- H = hand (manually operated valve)

The second letter is usually a "C" and identifies the valve as a controller, or active component, as opposed to a hand-operated valve. The third letter is a "V" to indicate that the piece of equipment is a valve.

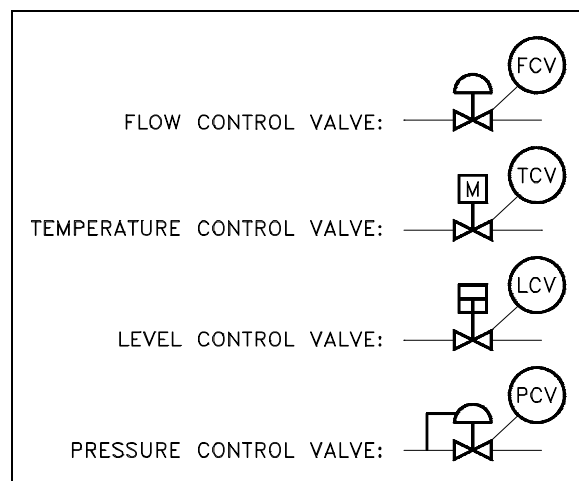


Figure 6 Control Valve Designations

Piping Systems

The piping of a single system may contain more than a single medium. For example, although the main process flow line may carry water, the associated auxiliary piping may carry compressed air, inert gas, or hydraulic fluid. Also, a fluid system diagram may also depict instrument signals and electrical wires as well as piping. Figure 7 shows commonly used symbols for indicating the medium carried by the piping and for differentiating between piping, instrumentation signals, and electrical wires. Note that, although the auxiliary piping symbols identify their mediums, the symbol for the process flow line does not identify its medium.

PROCESS FLOW LINE:	_____
PNEUMATIC (AIR) LINE OR DEFINED PROCESS LINE:	—//—//—//—//—
HYDRAULIC LINE:	— — — — —
ALTERNATIVE:	—L—L—L—L—L—
INERT GAS LINE:	—/—/—/—/—/—/—/—/—
INSTRUMENT SIGNAL:	— — — — —
INSTRUMENT CAPILLARY:	—x—x—x—x—x—x—x—x—
ELECTRICAL WIRES:	—●—●—●—●—●—●—●—●—
ALTERNATIVE:	— — — — —
ELECTRIC HEAT TRACING:	—E— — — E — — — E —
STEAM HEAT TRACING:	—S— — — S — — — S —

Figure 7 Piping Symbols

The diagram may also depict the individual fittings comprising the piping runs depending on its intended use. Figure 8 shows symbols used to depict pipe fittings.

Instrumentation

One of the main purposes of a P&ID is to provide functional information about how instrumentation in a system or piece of equipment interfaces with the system or piece of equipment. Because of this, a large amount of the symbology appearing on P&IDs depicts instrumentation and instrument loops.

The symbols used to represent instruments and their loops can be divided into four categories. Generally each of these four categories uses the component identifying (labeling) scheme identified in Table 1. The first column of Table 1 lists the letters used to identify the parameter being sensed or monitored by the loop or instrument. The second column lists the letters used to indicate the type of indicator or controller. The third column lists the letters used to indicate the type of component. The fourth column lists the letters used to indicate the type of signals that are being modified by a modifier.

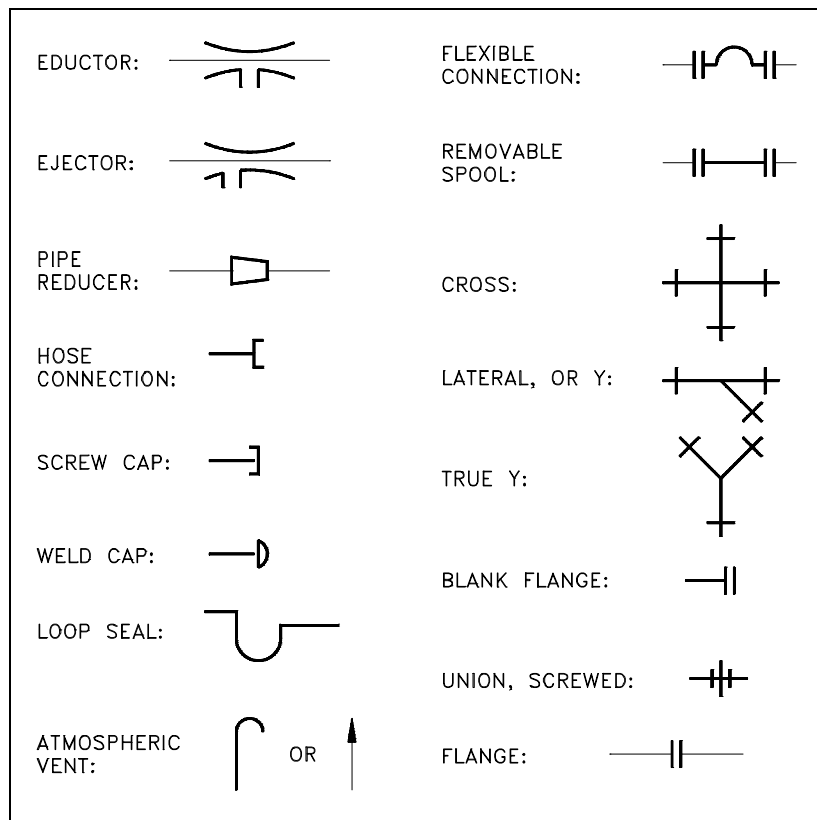


Figure 8 More Piping Symbols

TABLE 1
Instrument Identifiers

Sensed Parameter	Type of Indicator or Controller	Type of Component	Type of signal
F = flow T = temperature P = pressure I = current L = level V = voltage Z = position	R = recorder I = indicator C = controller	T = transmitter M = modifier E = element	I = current V = voltage P = pneumatic

The first three columns above are combined such that the resulting instrument identifier indicates its sensed parameter, the function of the instrument, and the type of instrument. The fourth column is used only in the case of an instrument modifier and is used to indicate the types of signals being modified. The following is a list of example instrument identifiers constructed from Table 1.

FIC = flow indicating controller
FM = flow modifier
PM = pressure modifier
TE = temperature element
TR = temperature recorder
LIC = level indicating controller

TT = temperature transmitter
PT = pressure transmitter
FE = flow element
FI = flow indicator
TI = temperature indicator
FC = flow controller

Sensing Devices and Detectors

The parameters of any system are monitored for indication, control, or both. To create a usable signal, a device must be inserted into the system to detect the desired parameter. In some cases, a device is used to create special conditions so that another device can supply the necessary measurement. Figure 9 shows the symbols used for the various sensors and detectors.

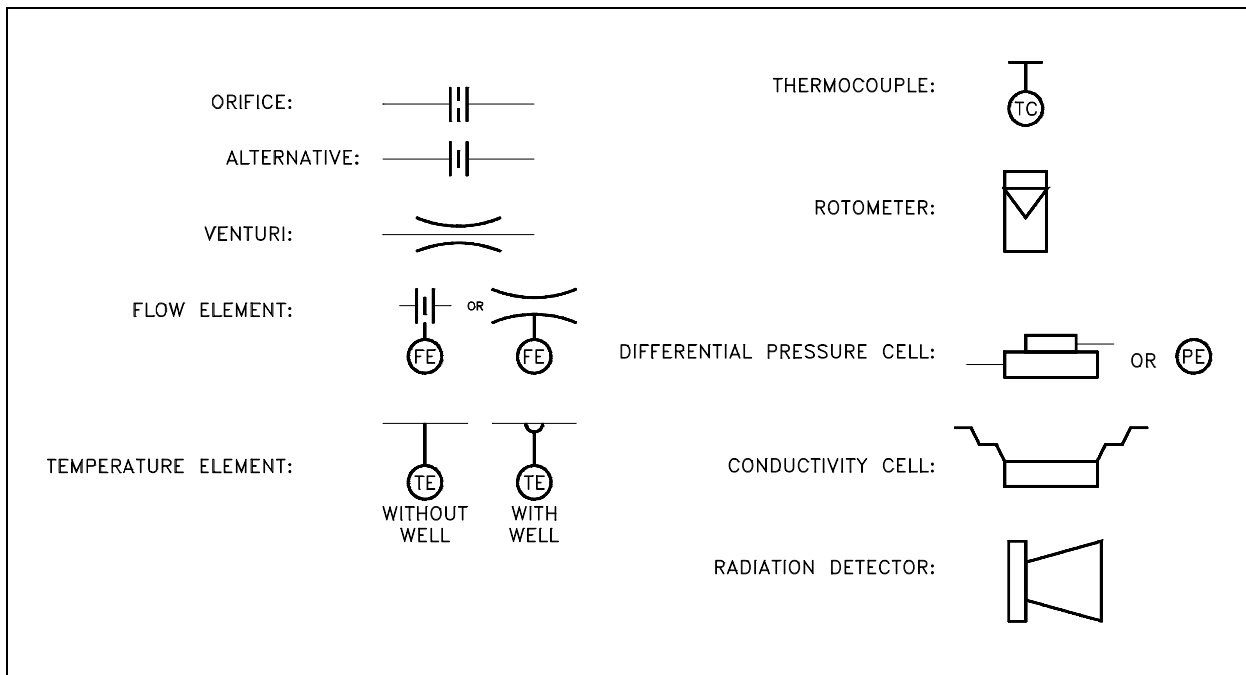


Figure 9 Detector and Sensing Device Symbols

Modifiers and Transmitters

Sensors and detectors by themselves are not sufficient to create usable system indications. Each sensor or detector must be coupled with appropriate modifiers and/or transmitters. The exceptions are certain types of local instrumentation having mechanical readouts, such as bourdon tube pressure gages and bimetallic thermometers. Figure 10 illustrates various examples of modifiers and transmitters. Figure 10 also illustrates the common notations used to indicate the location of an instrument, i.e., local or board mounted.

Transmitters are used to convert the signal from a sensor or detector to a form that can be sent to a remote point for processing, controlling, or monitoring. The output can be electronic (voltage or current), pneumatic, or hydraulic. Figure 10 illustrates symbols for several specific types of transmitters.

The reader should note that modifiers may only be identified by the type of input and output signal (such as I/P for one that converts an electrical input to a pneumatic output) rather than by the monitored parameter (such as PM for pressure modifier).

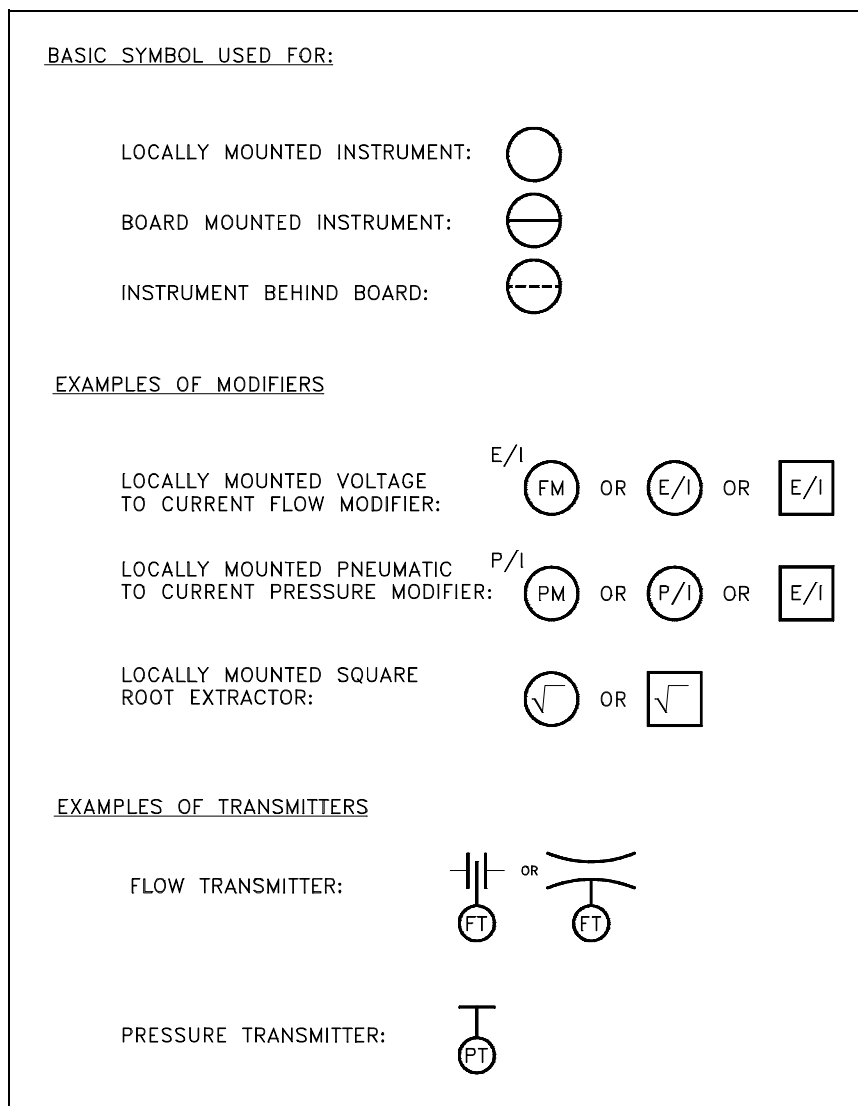


Figure 10 Transmitters and Instruments

Indicators and Recorders

Indicators and recorders are instruments that convert the signal generated by an instrument loop into a readable form. The indicator or recorder may be locally or board mounted, and like modifiers and transmitters this information is indicated by the type of symbol used. Figure 11 provides examples of the symbols used for indicators and recorders and how their location is denoted.

Controllers

Controllers process the signal from an instrument loop and use it to position or manipulate some other system component. Generally they are denoted by placing a "C" in the balloon after the controlling parameter as shown in Figure 12. There are controllers that serve to process a signal and create a new signal. These include proportional controllers, proportional-integral controllers, and proportional-integral-differential controllers. The symbols for these controllers are illustrated in Figure 13. Note that these types of controllers are also called signal conditioners.

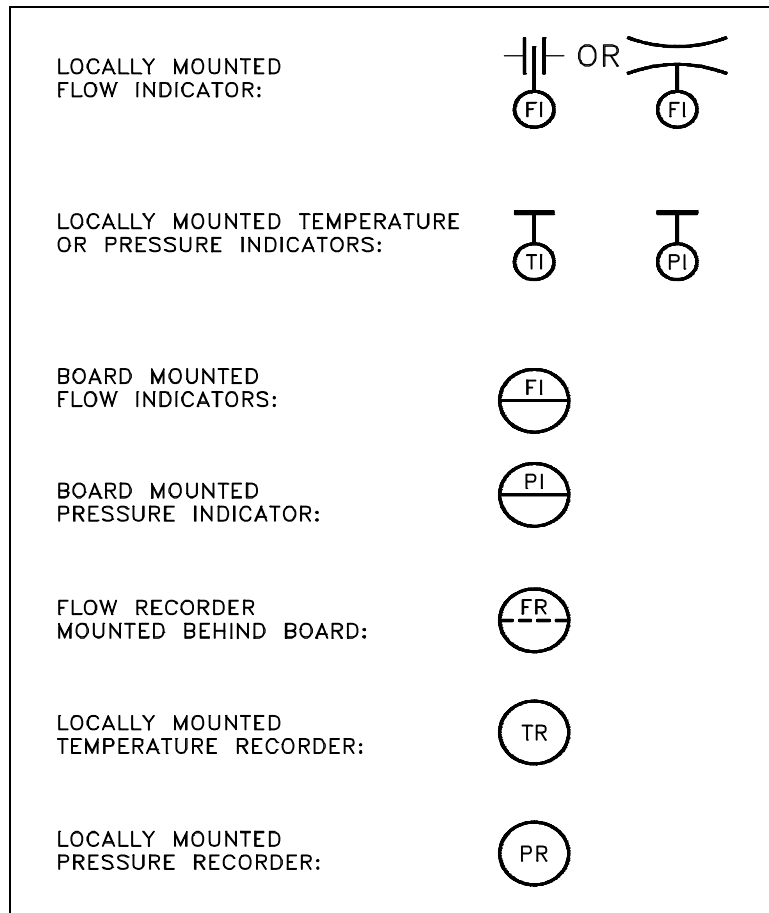


Figure 11 Indicators and Recorders

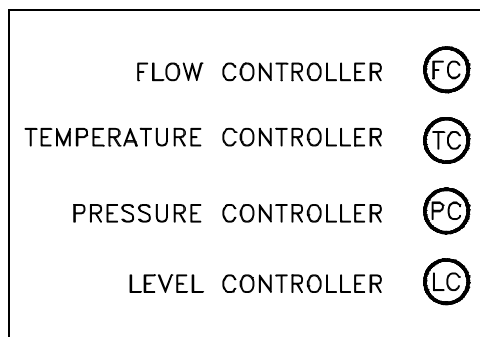


Figure 12 Controllers

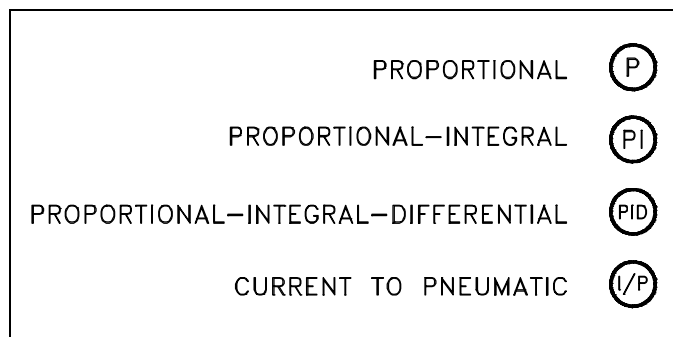


Figure 13 Signal Conditioners

Examples of Simple Instrument Loops

Figure 14 shows two examples of simple instrument loops. Figure 14 (A) shows a temperature transmitter (TT), which generates two electrical signals. One signal goes to a board-mounted temperature recorder (TR) for display. The second signal is sent to a proportional-integral-derivative (PID) controller, the output of which is sent to a current-to-pneumatic modifier (I/P). In the I/P modifier, the electric signal is converted into a pneumatic signal, commonly 3 psi to 15 psi, which in turn operates the valve. The function of the complete loop is to modify flow based on process fluid temperature. Note that there is not enough information to determine how flow and temperature are related and what the setpoint is, but in some instances the setpoint is stated on a P&ID. Knowing the setpoint and purpose of the system will usually be sufficient to allow the operation of the instrument loop to be determined.

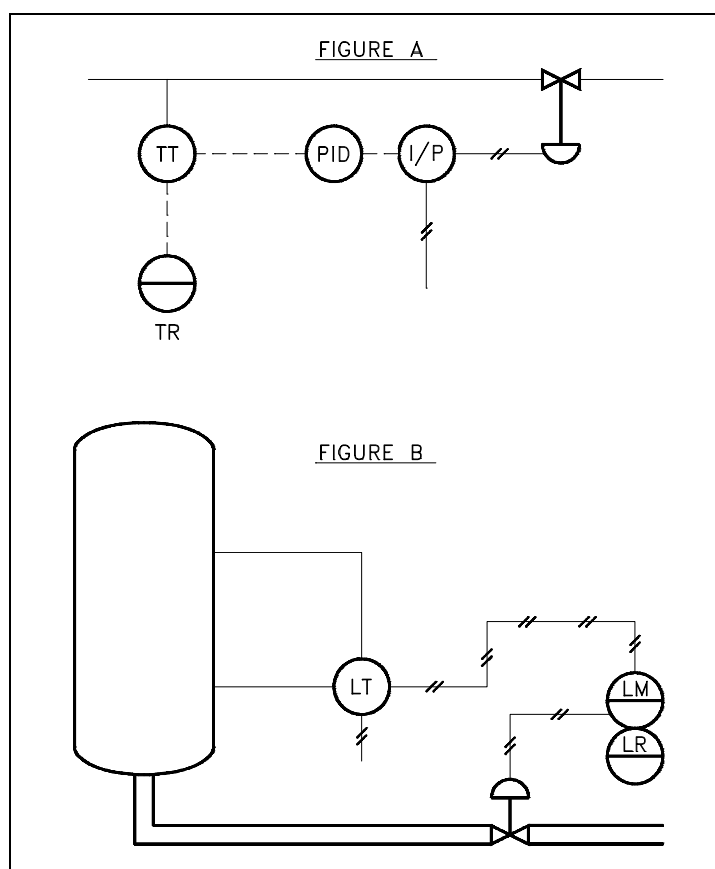


Figure 14 Instrumentation System Examples

The pneumatic level transmitter (LT) illustrated in Figure 14 (B) senses tank level. The output of the level transmitter is pneumatic and is routed to a board-mounted level modifier (LM). The level modifier conditions the signal (possibly boosts or mathematically modifies the signal) and uses the modified signal for two purposes. The modifier drives a board-mounted recorder (LR) for indication, and it sends a modified pneumatic signal to the diaphragm-operated level control valve. Notice that insufficient information exists to determine the relationship between sensed tank level and valve operation.

Components

Within every fluid system there are major components such as pumps, tanks, heat exchangers, and fans. Figure 15 shows the engineering symbols for the most common major components.

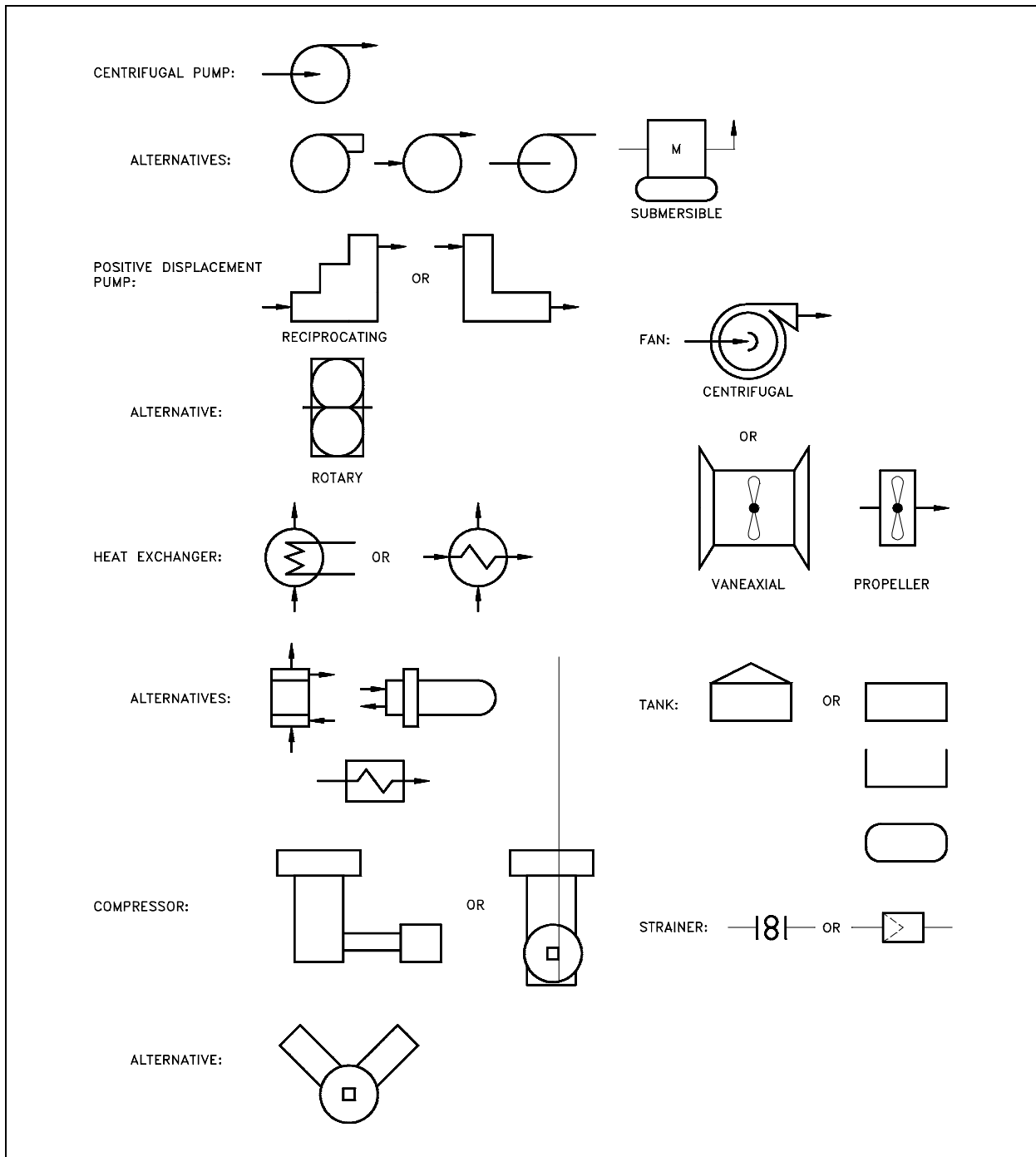


Figure 15 Symbols for Major Components

Miscellaneous P&ID Symbols

In addition to the normal symbols used on P&IDs to represent specific pieces of equipment, there are miscellaneous symbols that are used to guide or provide additional information about the drawing. Figure 16 lists and explains four of the more common miscellaneous symbols.

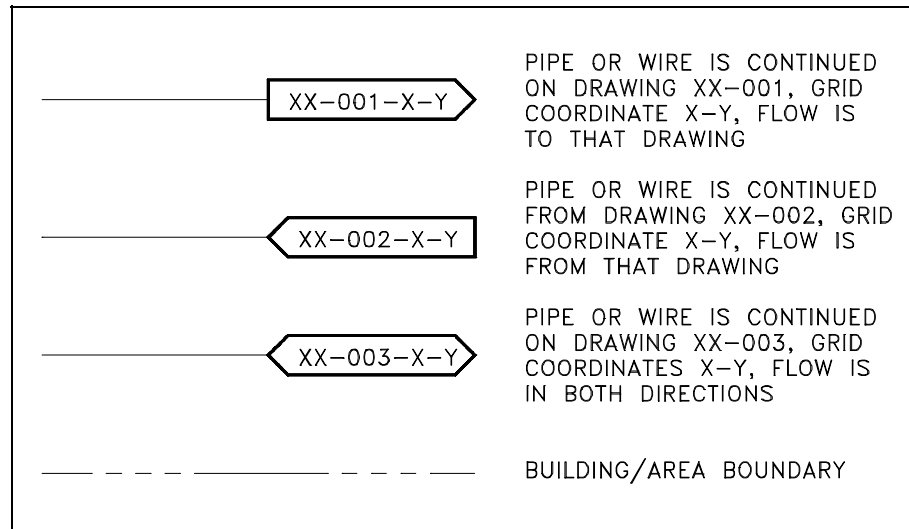


Figure 16 Miscellaneous Symbols

Summary

The important information in this chapter is summarized below.

Engineering Fluids Diagrams and Prints Summary

- In this chapter the common symbols found on P&IDs for valves, valve operators, process piping, instrumentation, and common system components were reviewed.

READING ENGINEERING P&IDs

Standards and conventions have been developed to provide consistency from drawing to drawing. To accurately interpret a drawing, these standards and conventions must be understood.

EO 1.9 **STATE** how the following valve conditions are depicted on an engineering P&ID drawing:

- | | |
|---|------------------------|
| a. Open valve | e. Locked-closed valve |
| b. Closed valve | f. Locked-open valve |
| c. Throttled valve | g. Fail-open valves |
| d. Combination valves
(3- or 4- way valve) | h. Fail-closed valve |
| | i. Fail-as-is valve |

Standards and Conventions for Valve Status

Before a diagram or print can be properly read and understood, the basic conventions used by P&IDs to denote valve positions and failure modes must be understood. The reader must be able to determine the valve position, know if this position is normal, know how the valve will fail, and in some cases know if the valve is normally locked in that position. Figure 17 illustrates the symbols used to indicate valve status. Unless otherwise stated, P&IDs indicate valves in their "normal" position. This is usually interpreted as the normal or primary flowpath for the system. An exception is safety systems, which are normally shown in their standby or non-accident condition.

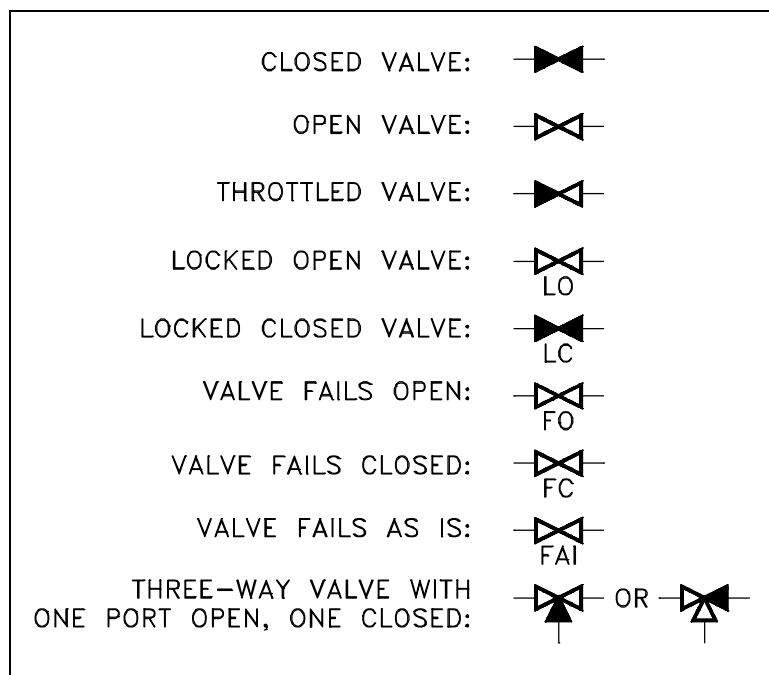


Figure 17 Valve Status Symbols

3-way valves are sometimes drawn in the position that they will fail to instead of always being drawn in their "normal" position. This will either be defined as the standard by the system of drawings or noted in some manner on the individual drawings.

Summary

The important information in this chapter is summarized below.

Reading Engineering P&IDs Summary

- This chapter reviewed the basic symbology, common standards, and conventions used on P&IDs, such as valve conditions and modes of failure. This information, with the symbology learned in the preceding chapter, provides the information necessary to read and interpret most P&IDs.

P&ID PRINT READING EXAMPLE

The ability to read and understand prints is achieved through the repetitive reading of prints.

EO 1.10 Given an engineering P&ID, IDENTIFY components and DETERMINE the flowpath(s) for a given valve lineup.

Example

At this point, all the symbols for valves and major components have been presented, as have the conventions for identifying the condition of a system. Refer to Figure 18 as necessary to answer the following questions. The answers are provided in the back of this section so that you may judge your own knowledge level.

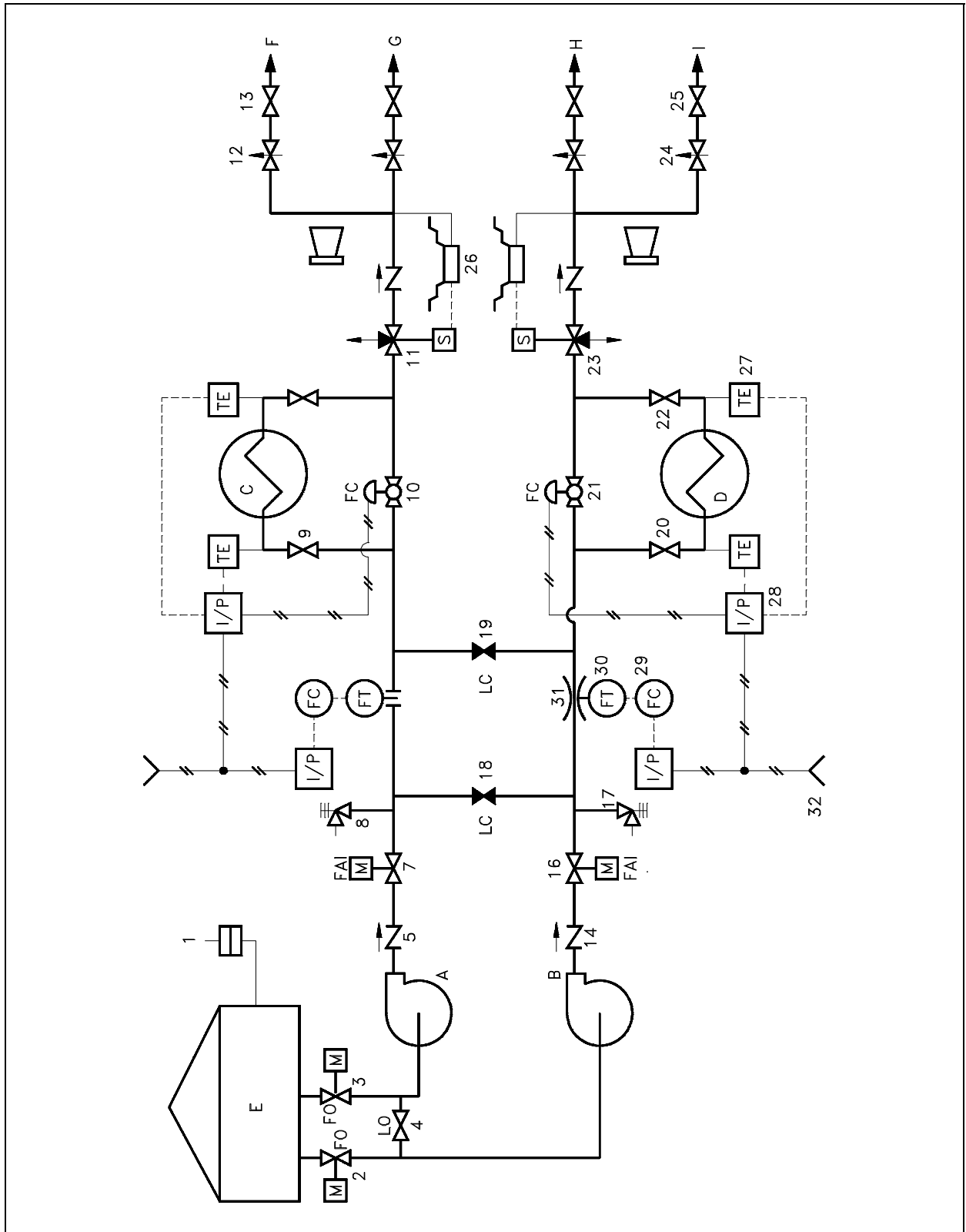


Figure 18 Exercise P&ID

1. Identify the following components by letter or number.

- ☐ a. Centrifugal pump
- ☐ b. Heat exchanger
- ☐ c. Tank
- ☐ d. Venturi
- ☐ e. Rupture disc
- ☐ f. Relief valve
- ☐ g. Motor-operated valve
- ☐ h. Air-operated valve
- ☐ i. Throttle valve
- ☐ j. Conductivity cell
- ☐ k. Air line
- ☐ l. Current-to-pneumatic converter
- ☐ m. Check valve
- ☐ n. A locked-closed valve
- ☐ o. A closed valve
- ☐ p. A locked-open valve
- ☐ q. A solenoid valve

2. What is the controlling parameter for Valves 10 and 21?

3. Which valves would need to change position in order for Pump B to supply flow to only points G and H?

4. Which valves will fail open? Fail closed? Fail as is?

Answers for questions on Figure 18

1.
 - a. A or B
 - b. C or D
 - c. E
 - d. 31
 - e. 1
 - f. 8 or 17
 - g. 2,3,7 or 16
 - h. 10, 21
 - i. 12 or 24
 - j. 26
 - k. 32
 - l. 28
 - m. 5 or 14
 - n. 18 or 19
 - o. 18 or 19
 - p. 4
 - q. 11 or 23
2. Temperature as sensed by the temperature elements (TE)
3. Open 18 and/or 19
Shut 13 and 25
4. Fail Open: 2 and 3
Fail Closed: 10 and 21
Fail as is: 7 and 16

Summary

The important information in this chapter is summarized below.

P&ID Print Reading Example Summary

- This chapter provided the student with examples in applying the material learned in Chapters 1 and 2.

FLUID POWER P&IDs

Fluid power diagrams and schematics require an independent review because they use a unique set of symbols and conventions.

EO 1.11 IDENTIFY the symbols used on engineering fluid power drawings for the following components:

- | | |
|----------------------|---------------------------------------|
| a. Pump | d. Actuators |
| b. Compressor | e. Piping and piping junctions |
| c. Reservoir | f. Valves |

EO 1.12 Given a fluid power type drawing, DETERMINE the operation or resultant action of the stated component when hydraulic pressure is applied/removed.

Fluid Power Diagrams and Schematics

Different symbology is used when dealing with systems that operate with fluid power. Fluid power includes either gas (such as air) or hydraulic (such as water or oil) motive media. Some of the symbols used in fluid power systems are the same or similar to those already discussed, but many are entirely different.

Fluid power systems are divided into five basic parts: pumps, reservoirs, actuators, valves, and lines.

Pumps

In the broad area of fluid power, two categories of pump symbols are used, depending on the motive media being used (i.e., hydraulic or pneumatic). The basic symbol for the pump is a circle containing one or more arrow heads indicating the direction(s) of flow with the points of the arrows in contact with the circle. Hydraulic pumps are shown by solid arrow heads. Pneumatic compressors are represented by hollow arrow heads. Figure 19 provides common symbols used for pumps (hydraulic) and compressors (pneumatic) in fluid power diagrams.

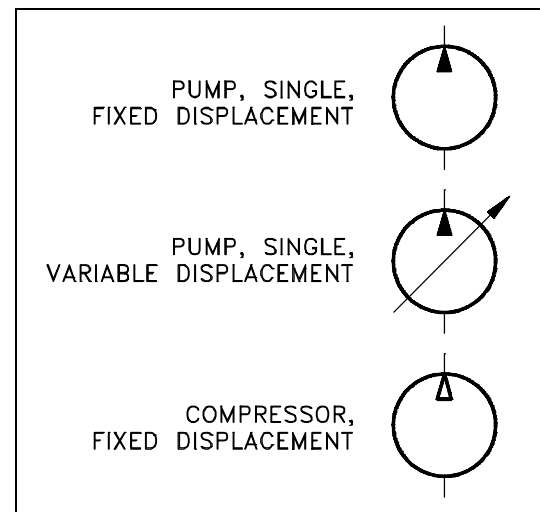


Figure 19 Fluid Power Pump and Compressor Symbols

Reservoirs

Reservoirs provide a location for storage of the motive media (hydraulic fluid or compressed gas). Although the symbols used to represent reservoirs vary widely, certain conventions are used to indicate how a reservoir handles the fluid. Pneumatic reservoirs are usually simple tanks and their symbology is usually some variation of the cylinder shown in Figure 20. Hydraulic reservoirs can be much more complex in terms of how the fluid is admitted to and removed from the tank. To convey this information, symbology conventions have been developed. These symbols are in Figure 20.

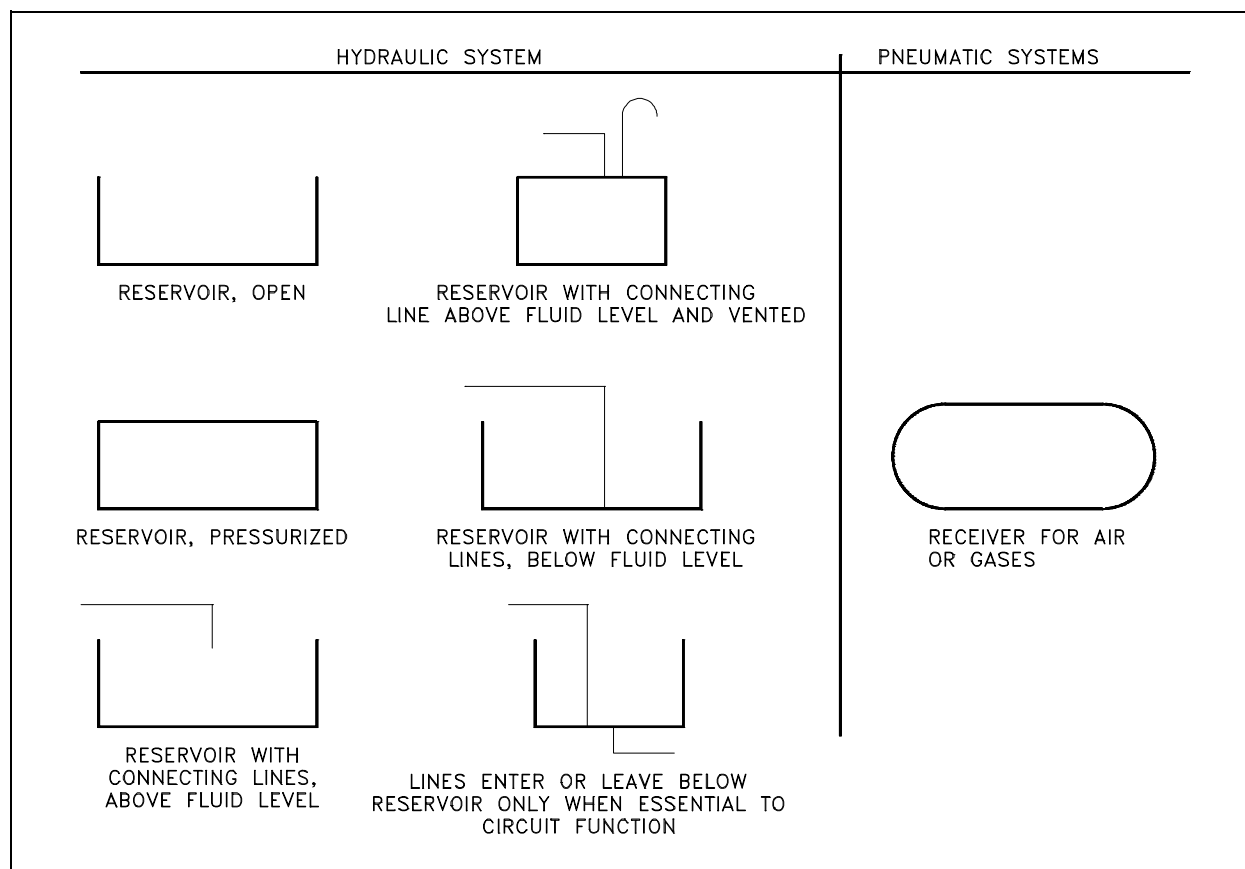


Figure 20 Fluid Power Reservoir Symbols

Actuator

An actuator in a fluid power system is any device that converts the hydraulic or pneumatic pressure into mechanical work. Actuators are classified as linear actuators and rotary actuators. Linear actuators have some form of piston device. Figure 21 illustrates several types of linear actuators and their drawing symbols.

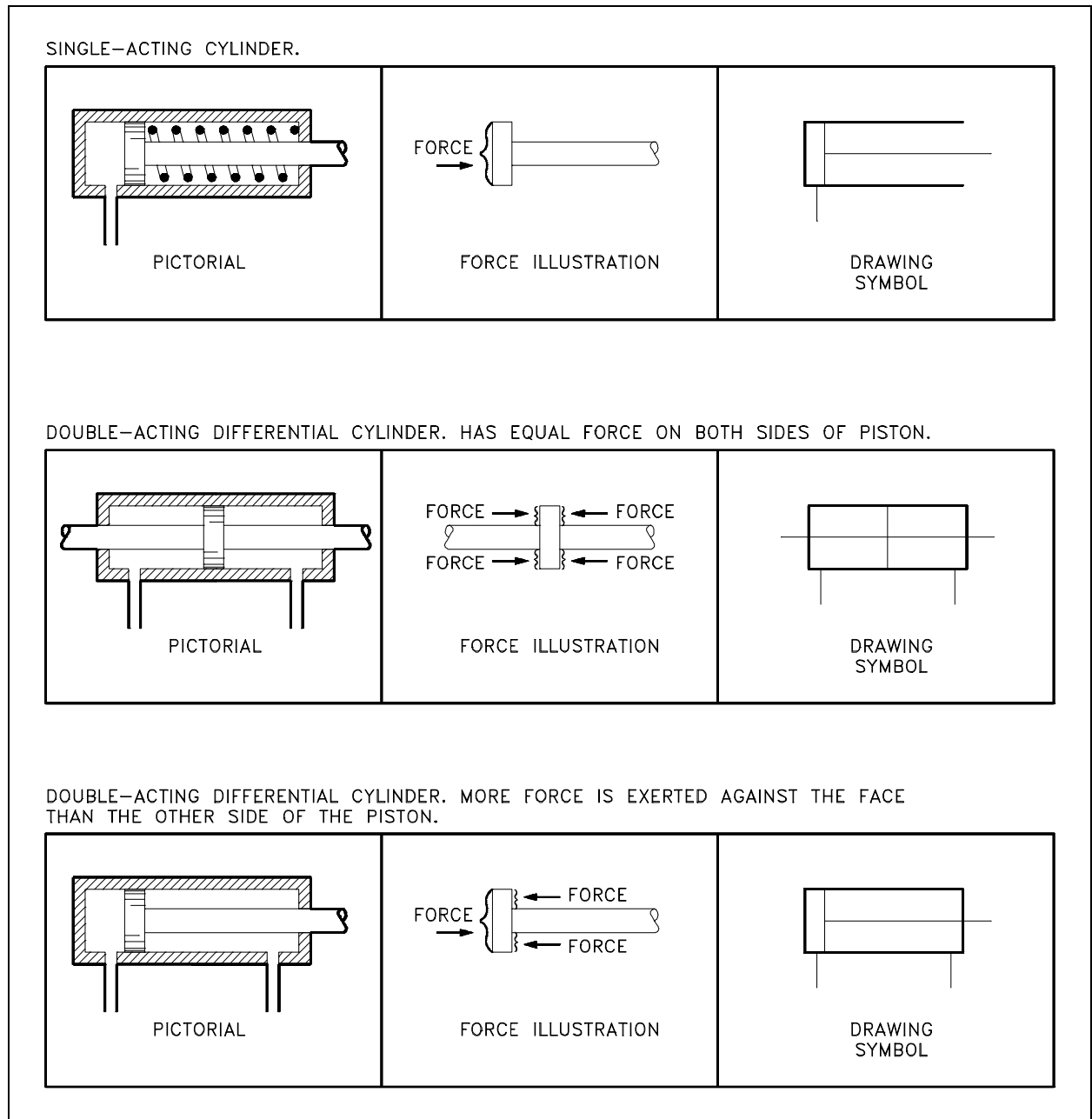


Figure 21 Symbols for Linear Actuators

Rotary actuators are generally called motors and may be fixed or variable. Several of the more common rotary symbols are shown in Figure 22. Note the similarity between rotary motor symbols in Figure 22 and the pump symbols shown in Figure 19. The difference between them is that the point of the arrow touches the circle in a pump and the tail of the arrow touches the circle in a motor.

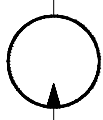
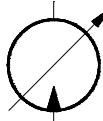

MOTOR, ROTARY, FIXED DISPLACEMENT	
MOTOR, ROTARY, VARIABLE DISPLACEMENT	
MOTOR, OSCILLATING	

Figure 22 Symbols for Rotary Actuators

Piping

The sole purpose of piping in a fluid power system is to transport the working media, at pressure, from one point to another. The symbols for the various lines and termination points are shown in Figure 23.


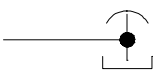
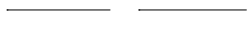

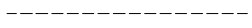


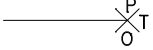

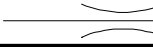

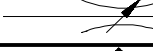

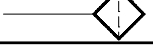


LINE, WORKING		LINE TO VENTED MANIFOLD	
LINE, PILOT		PLUG OR PLUGGED CONNECTION	
LINE, DRAIN		TESTING STATION (GAGE CONNECTION)	
CONNECTOR (DOT TO BE 5X WIDTH OF LINE)		POWER TAKEOFF (HYD.)	
LINE, FLEXIBLE		RESTRICTION, FIXED	
LINE, JOINING		RESTRICTION, VARIABLE	
LINE, CROSSING		STRAINER	
DIRECTION OF FLOW			
LINE TO RESERVOIR ABOVE FLUID LEVEL BELOW FLUID LEVEL			

Figure 23 Fluid Power Line Symbols

Valves

Valves are the most complicated symbols in fluid power systems. Valves provide the control that is required to ensure that the motive media is routed to the correct point when needed. Fluid power system diagrams require much more complex valve symbology than standard P&IDs due to the complicated valving used in fluid power systems. In a typical P&ID, a valve opens, closes, or throttles the process fluid, but is rarely required to route the process fluid in any complex manner (three- and four-way valves being the common exceptions). In fluid power systems it is common for a valve to have three to eight pipes attached to the valve body, with the valve being capable of routing the fluid, or several separate fluids, in any number of combinations of input and output flowpaths.

The symbols used to represent fluid power valves must contain much more information than the standard P&ID valve symbology. To meet this need, the valve symbology shown in the following figures was developed for fluid power P&IDs. Figure 24, a cutaway view, provides an example of the internal complexity of a simple fluid power type valve. Figure 24 illustrates a four-way/three-position valve and how it operates to vary the flow of the fluid. Note that in Figure 24 the operator of the valve is not identified, but like a standard process fluid valve the valve could be operated by a diaphragm, motor, hydraulic, solenoid, or manual operator. Fluid power valves, when electrically operated by a solenoid, are drawn in the de-energized position. Energizing the solenoid will cause the valve to shift to the other port. If the valve is operated by other than a solenoid or is a multiport valve, the information necessary to determine how the valve operates will be provided on each drawing or on its accompanying legend print.

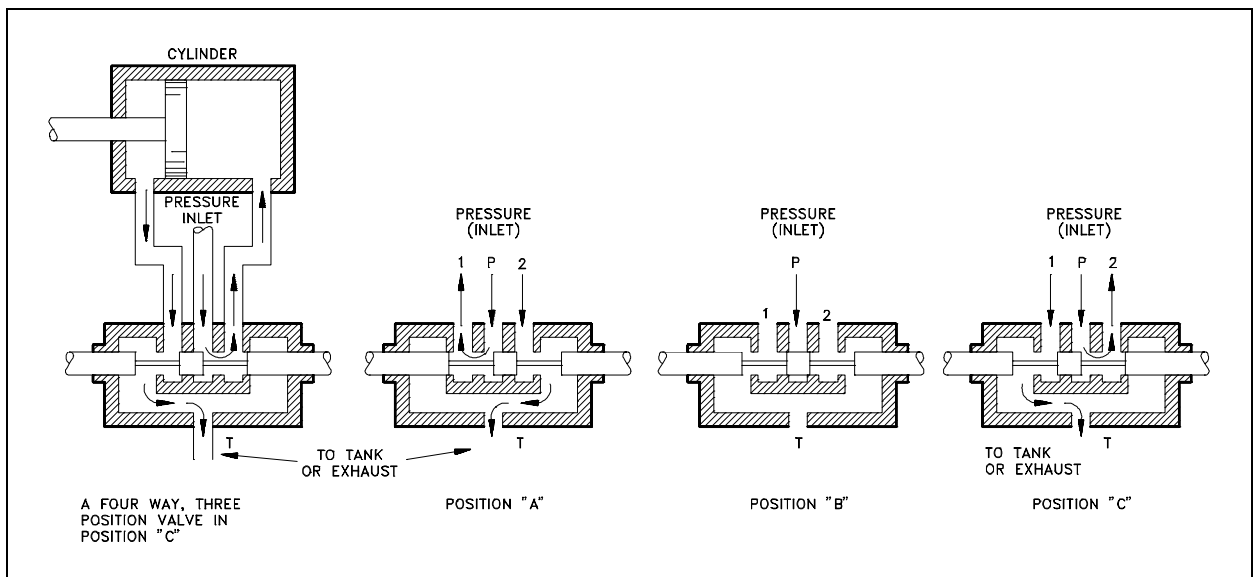


Figure 24 Valve Operation

Refer to Figure 25 to see how the valve in Figure 24 is transformed into a usable symbol.

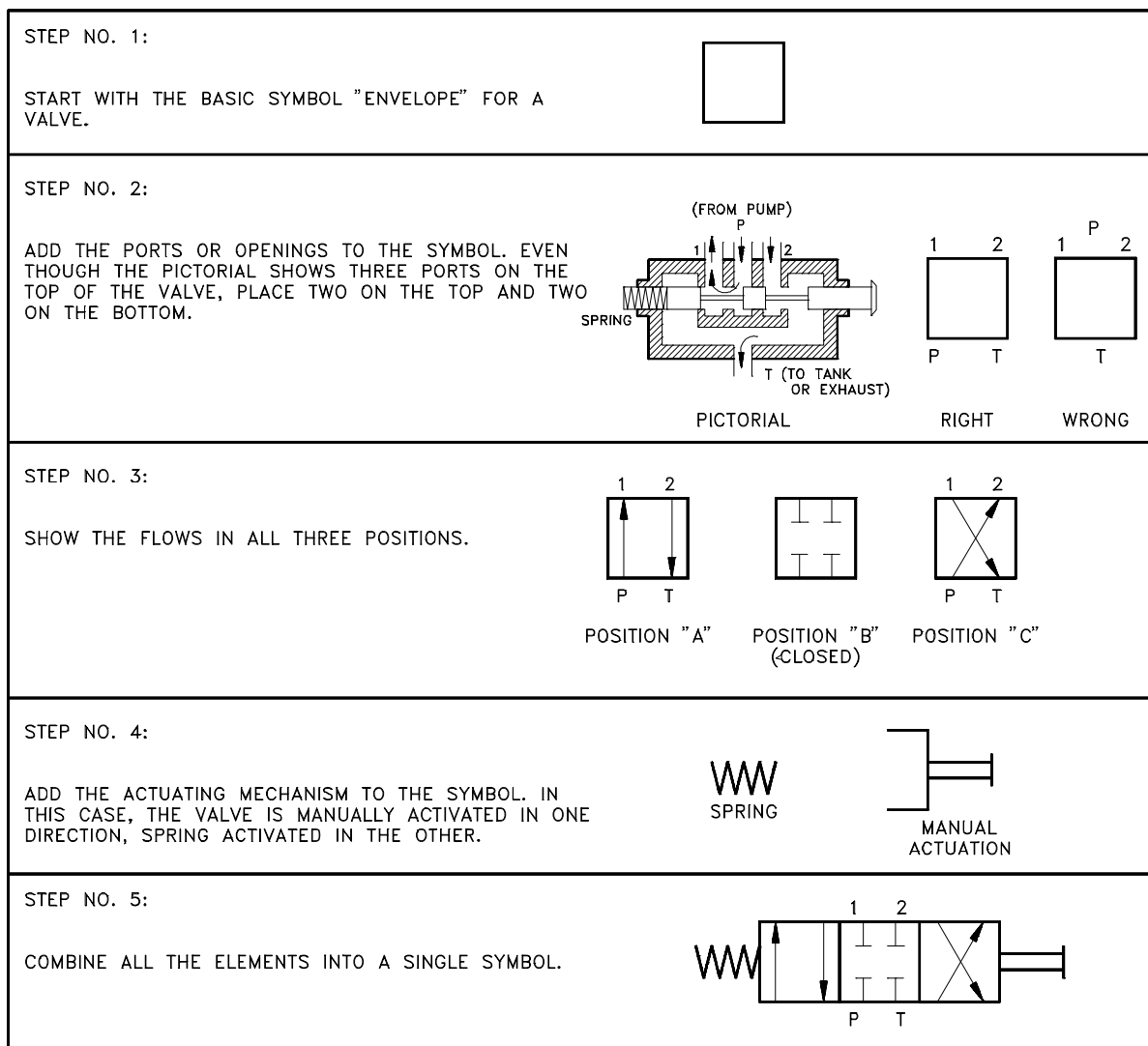


Figure 25 Valve Symbol Development

Figure 26 shows symbols for the various valve types used in fluid power systems.



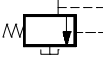





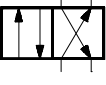
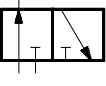
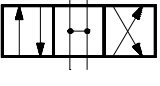
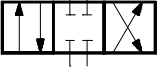
VALVE, CHECK	
VALVE, MANUAL SHUTOFF	
VALVE, MAXIMUM PRESSURE (RELIEF)	
VALVE, BASIC SYMBOL SINGLE FLOW PATH IS MODIFIED	
VALVE, BASIC SYMBOL MULTIPLE FLOW PATHS ARE CHANGED	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, MULTIPLE FLOW PATHS, BLOCKED	
VALVE, MULTIPLE FLOW PATHS, OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, DIRECTIONAL, 2 POSITION 3 CONNECTIONS	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTIONS OPEN CENTER	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTIONS CLOSED CENTER	

Figure 26 Fluid Power Valve Symbols

Reading Fluid Power Diagrams

Using the symbology previously discussed, a fluid power diagram can now be read. But before reading some complex examples, let's look at a simple hydraulic system and convert it into a fluid power diagram.

Using the drawing in Figure 27, the left portion of Figure 28 lists each part and its fluid power symbol. The right side of Figure 28 shows the fluid power diagram that represents the drawing in Figure 27.

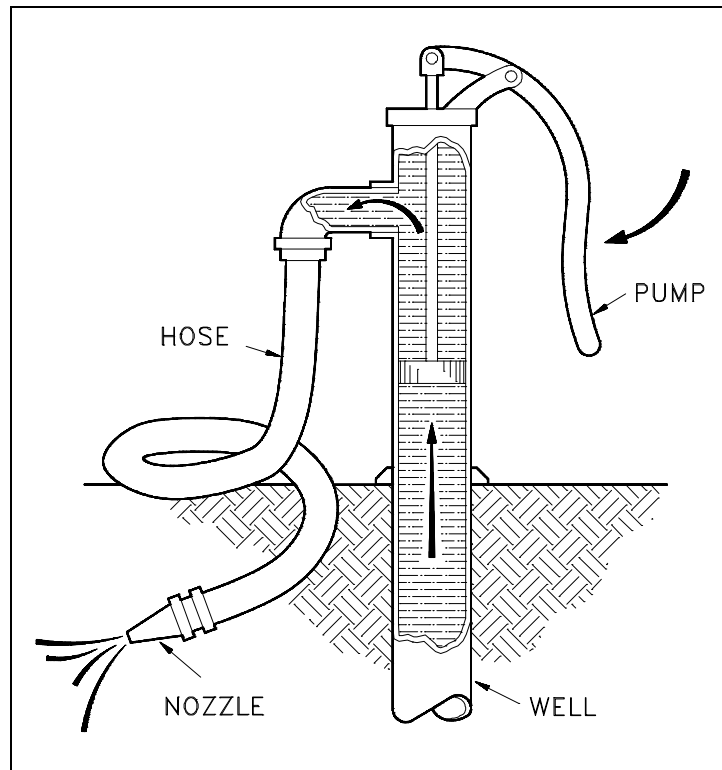


Figure 27 Simple Hydraulic Power System

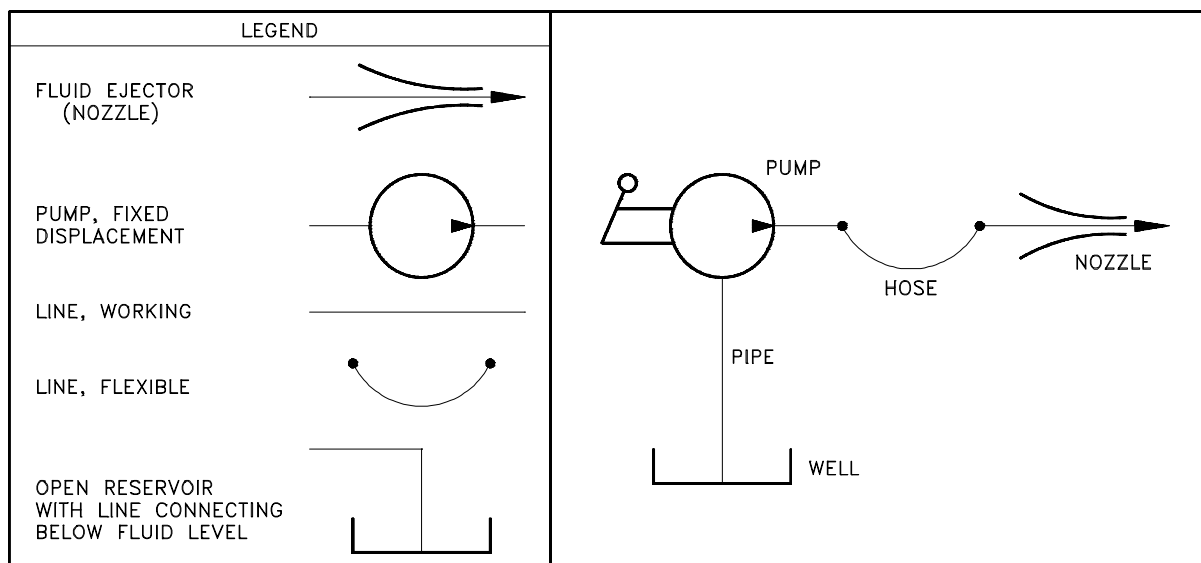


Figure 28 Line Diagram of Simple Hydraulic Power System

With an understanding of the principles involved in reading fluid power diagram, any diagram can be interpreted. Figure 29 shows the kind of diagram that is likely to be encountered in the engineering field. To read this diagram, a step-by-step interpretation of what is happening in the system will be presented.

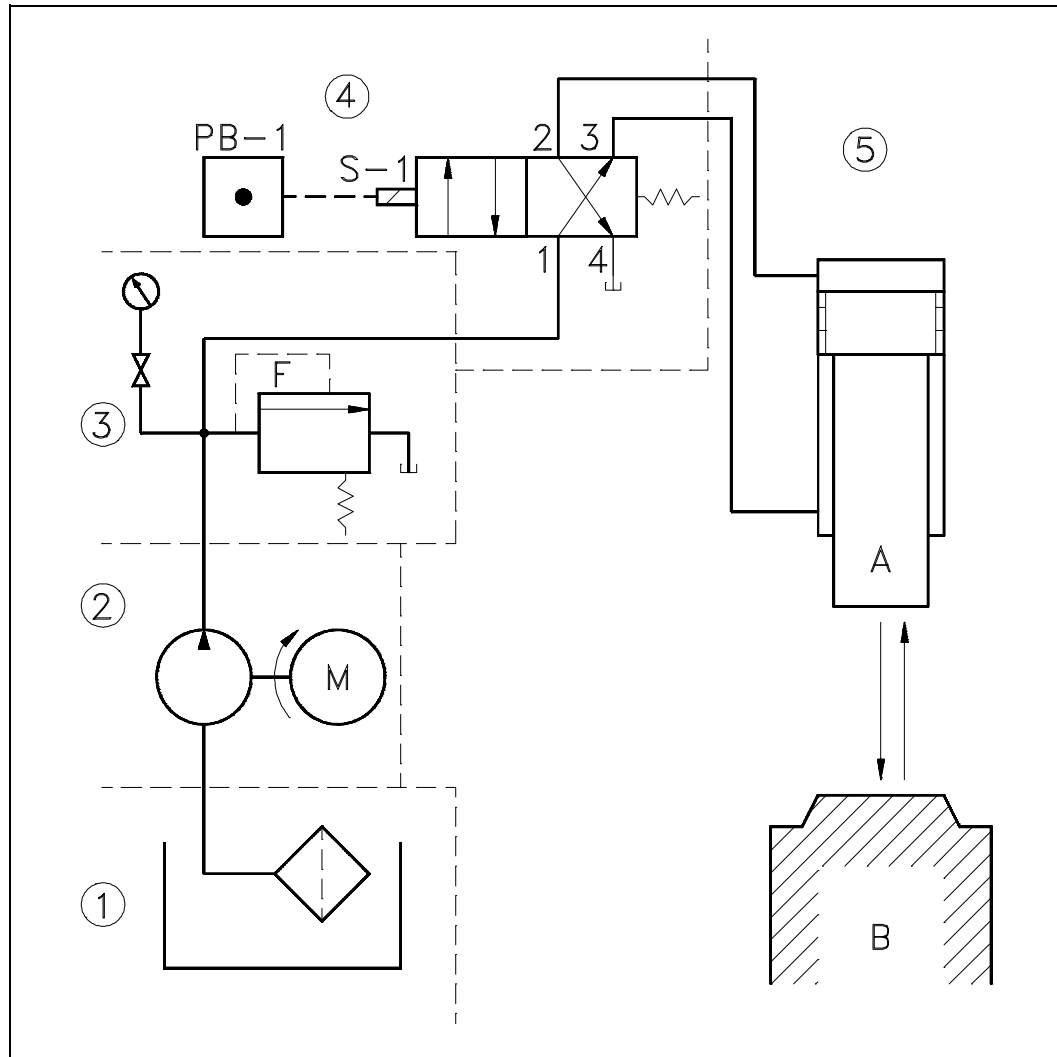


Figure 29 Typical Fluid Power Diagram

The first step is to get an overall view of what is happening. The arrows between A and B in the lower right-hand corner of the figure indicate that the system is designed to press or clamp some type of part between two sections of the machine. Hydraulic systems are often used in press work or other applications where the work piece must be held in place.

With the basic function understood, a detailed study of the diagram can be accomplished using a step-by-step analysis of each numbered local area in the diagram.

LOCAL AREA NUMBER 1

Symbol for an open reservoir with a strainer. The strainer is used to clean the oil before it enters the system.

LOCAL AREA NUMBER 2

Fixed displacement pump, electrically operated. This pump provides hydraulic pressure to the system.

LOCAL AREA NUMBER 3

Symbol for a relief valve with separate pressure gage. The relief valve is spring operated and protects the system from over pressurization. It also acts as an unloader valve to relieve pressure when the cylinder is not in operation. When system pressure exceeds its setpoint, the valve opens and returns the hydraulic fluid back to the reservoir. The gage provides a reading of how much pressure is in the system.

LOCAL AREA NUMBER 4

Composite symbol for a 4-way, 2-position valve. Pushbutton PB-1 is used to activate the valve by energizing the S-1 solenoid (note the valve is shown in the de-energized position). As shown, the high pressure hydraulic fluid is being routed from Port 1 to Port 3 and then to the bottom chamber of the piston. This drives and holds the piston in local area #5 in the retracted position. When the piston is fully retracted and hydraulic pressure builds, the unloader (relief) valve will lift and maintain the system's pressure at setpoint.

When PB-1 is pushed and S-1 energized, the 1-2 ports are aligned and 3-4 ports are aligned. This allows hydraulic fluid to enter the top chamber of the piston and drive it down. The fluid in the bottom chamber drains through the 3-4 ports back into the reservoir. The piston will continue to travel down until either PB-1 is released or full travel is reached, at which point the unloader (relief) valve will lift.

LOCAL AREA NUMBER 5

Actuating cylinder and piston. The cylinder is designed to receive fluid in either the upper or lower chambers. The system is designed so that when pressure is applied to the top chamber, the bottom chamber is aligned to drain back to the reservoir. When pressure is applied to the bottom chamber, the top chamber is aligned so that it drains back to the reservoir.

Types of Fluid Power Diagrams

Several kinds of diagrams can be used to show how systems work. With an understanding of how to interpret Figure 29, a reader will be able to interpret all of the diagrams that follow.

A pictorial diagram shows the physical arrangement of the elements in a system. The components are outline drawings that show the external shape of each item. Pictorial drawings do not show the internal function of the elements and are not especially valuable for maintenance or troubleshooting. Figure 30 shows a pictorial diagram of a system.

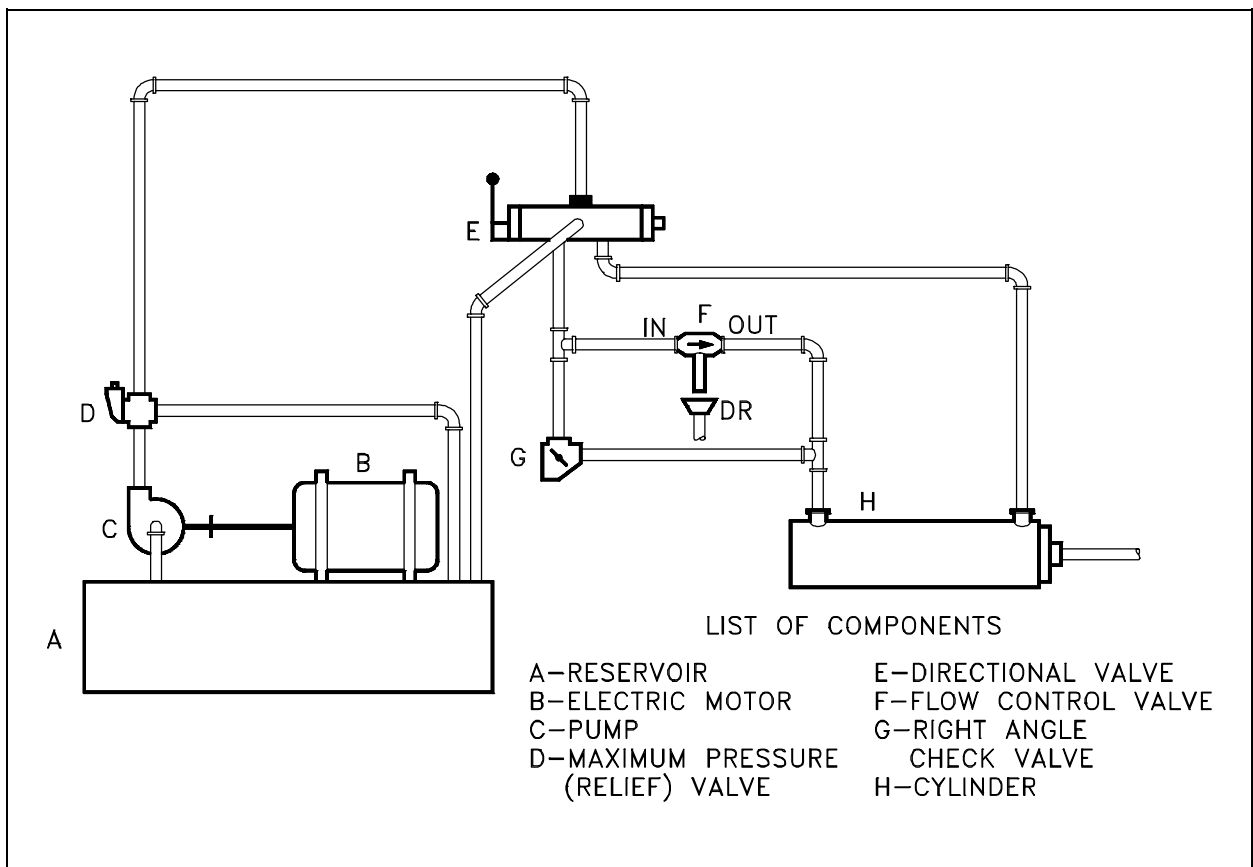


Figure 30 Pictorial Fluid Power Diagram

A cutaway diagram shows both the physical arrangement and the operation of the different components. It is generally used for instructional purposes because it explains the functions while showing how the system is arranged. Because these diagrams require so much space, they are not usually used for complicated systems. Figure 31 shows the system represented in Figure 30 in cutaway diagram format and illustrates the similarities and differences between the two types of diagrams.

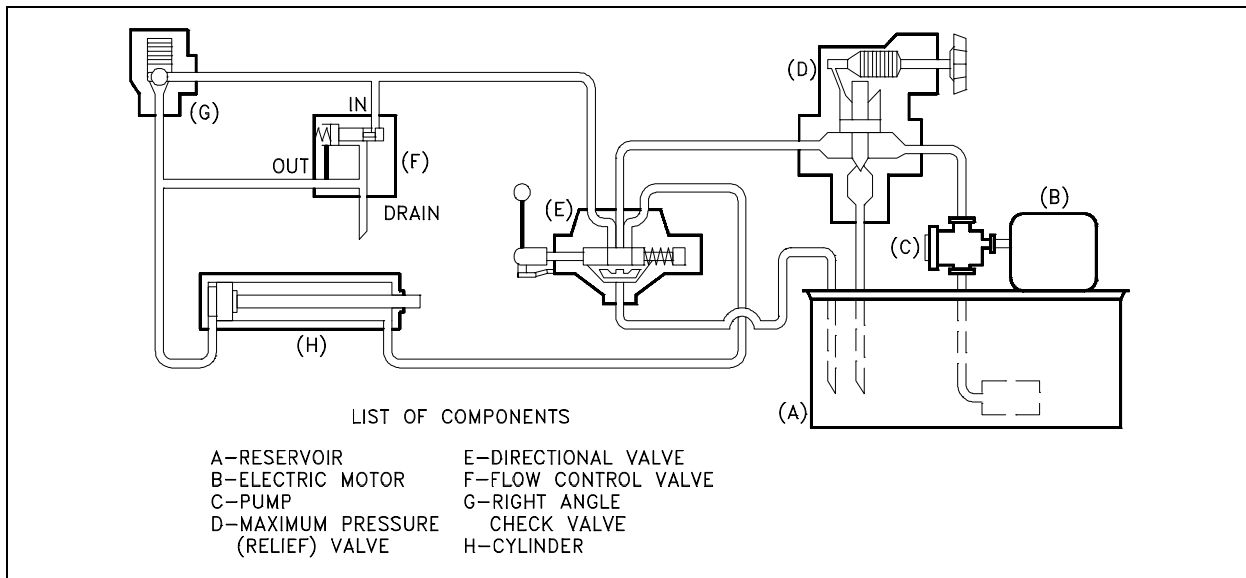


Figure 31 Cutaway Fluid Power Diagram

A schematic diagram uses symbols to show the elements in a system. Schematics are designed to supply the functional information of the system. They do not accurately represent the relative location of the components. Schematics are useful in maintenance work, and understanding them is an important part of troubleshooting. Figure 32 is a schematic diagram of the system illustrated in Figure 30 and Figure 31.

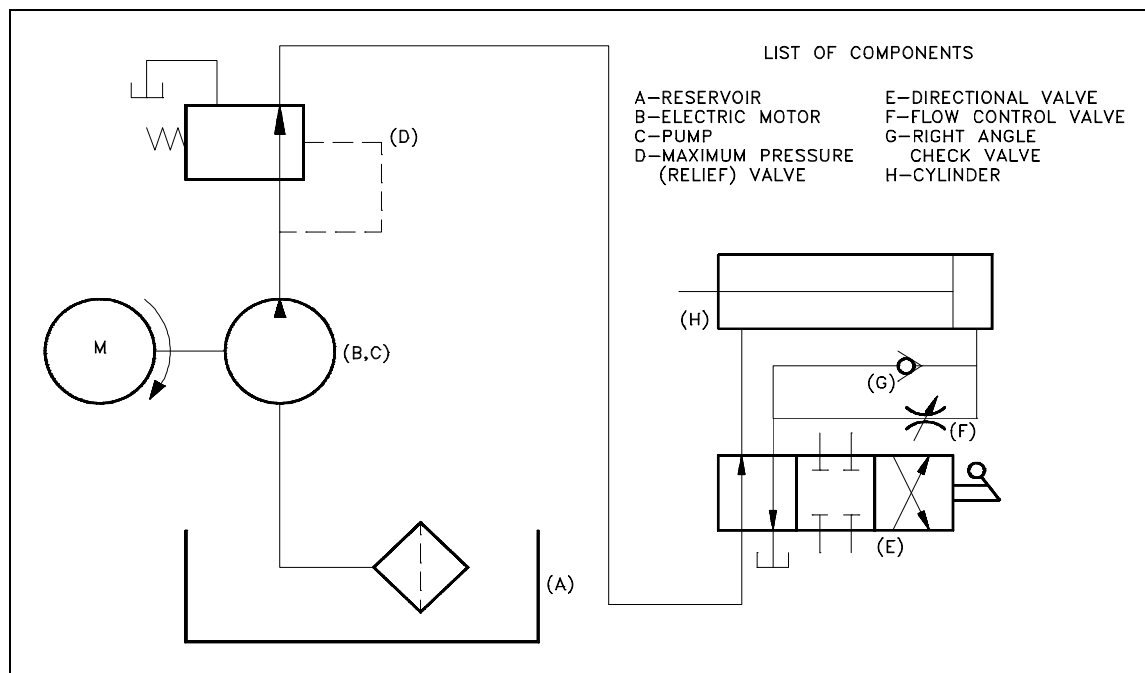


Figure 32 Schematic Fluid Power Diagram

Summary

The important information in this chapter is summarized below.

Fluid Power P&IDs Summary

- This chapter reviewed the most commonly used symbols on fluid power diagrams and the basic standards and conventions for reading and interpreting fluid power diagrams.

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Department of Energy
Fundamentals Handbook

**ENGINEERING SYMBOLOGY, PRINTS,
AND DRAWINGS**

Module 3

Electrical Diagrams and Schematics

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TERMINAL OBJECTIVE

- 1.0 Given an electrical print, **READ** and **INTERPRET** facility electrical diagrams and schematics.

ENABLING OBJECTIVES

- 1.1 **IDENTIFY** the symbols used on engineering electrical drawings for the following components:

- | | |
|---|-----------------------------|
| a. Single-phase circuit breaker (open/closed) | m. Electric motor |
| b. Three-phase circuit breaker (open/closed) | n. Meters |
| c. Thermal overload | o. Junctions |
| d. "a" contact | p. In-line fuses |
| e. "b" contact | q. Single switch |
| f. Time-delay contacts | r. Multiple-position switch |
| g. Relay | s. Pushbutton switch |
| h. Potential transformer | t. Limit switches |
| i. Current transformer | u. Turbine-driven generator |
| j. Single-phase transformer | v. Motor-generator set |
| k. Delta-wound transformer | w. Generator (wye or delta) |
| l. Wye-wound transformer | x. Diesel-driven generator |
| | y. Battery |

- 1.2 Given an electrical drawing of a circuit containing a transformer, **DETERMINE** the direction of current flow, as shown by the transformer's symbol.

- 1.3 **IDENTIFY** the symbols and/or codes used on engineering electrical drawings to depict the relationship between the following components:

- a. Relay and its contacts
- b. Switch and its contacts
- c. Interlocking device and its interlocked equipment

ENABLING OBJECTIVES (Cont.)

- 1.4 **STATE** the condition in which all electrical devices are shown, unless otherwise noted on the diagram or schematic.
- 1.5 Given a simple electrical schematic and initial conditions, **DETERMINE** the condition of the specified component (i.e., energized/de-energized, open/closed).
- 1.6 Given a simple electrical schematic and initial conditions, **IDENTIFY** the power sources and/or loads and their status (i.e., energized or de-energized).

ELECTRICAL DIAGRAMS AND SCHEMATICS

To read and interpret electrical diagrams and schematics, the basic symbols and conventions used in the drawing must be understood. This chapter concentrates on how electrical components are represented on diagrams and schematics. The function of the individual electrical components and the theory behind their operation is covered in more detail in the Electrical Science Handbook.

EO 1.1 IDENTIFY the symbols used on engineering electrical drawings for the following components:

- | | |
|---|-----------------------------|
| a. Single-phase circuit breaker (open/closed) | m. Electric motor |
| b. Three-phase circuit breaker (open/closed) | n. Meters |
| c. Thermal overload | o. Junctions |
| d. "a" contact | p. In-line fuses |
| e. "b" contact | q. Single switch |
| f. Time-delay contacts | r. Multiple-position switch |
| g. Relay | s. Pushbutton switch |
| h. Potential transformer | t. Limit switches |
| i. Current transformer | u. Turbine-driven generator |
| j. Single-phase transformer | v. Motor-generator set |
| k. Delta-wound transformer | w. Generator (wye or delta) |
| l. Wye-wound transformer | x. Diesel-driven generator |
| | y. Battery |

EO 1.2 Given an electrical drawing of a circuit containing a transformer, DETERMINE the direction of current flow, as shown by the transformer's symbol.

EO 1.3 IDENTIFY the symbols and/or codes used on engineering electrical drawings to depict the relationship between the following components:

- a. Relay and its contacts
- b. Switch and its contacts
- c. Interlocking device and its interlocked equipment

EO 1.4 STATE the condition in which all electrical devices are shown, unless otherwise noted on the diagram or schematic.

EO 1.5 Given a simple electrical schematic and initial conditions, DETERMINE the condition of the specified component (i.e., energized/de-energized, open/closed).

Symbology

To read and interpret electrical diagrams and schematics, the reader must first be well versed in what the many symbols represent. This chapter discusses the common symbols used to depict the many components in electrical systems. Once mastered, this knowledge should enable the reader to successfully understand most electrical diagrams and schematics.

The information that follows provides details on the basic symbols used to represent components in electrical transmission, switching, control, and protection diagrams and schematics.

Transformers

The basic symbols for the various types of transformers are shown in Figure 1 (A). Figure 1 (B) shows how the basic symbol for the transformer is modified to represent specific types and transformer applications.

In addition to the transformer symbol itself, polarity marks are sometimes used to indicate current flow in the circuit. This information can be used to determine the phase relationship (polarity) between the input and output terminals of a transformer. The marks usually appear as dots on a transformer symbol, as shown in Figure 2.

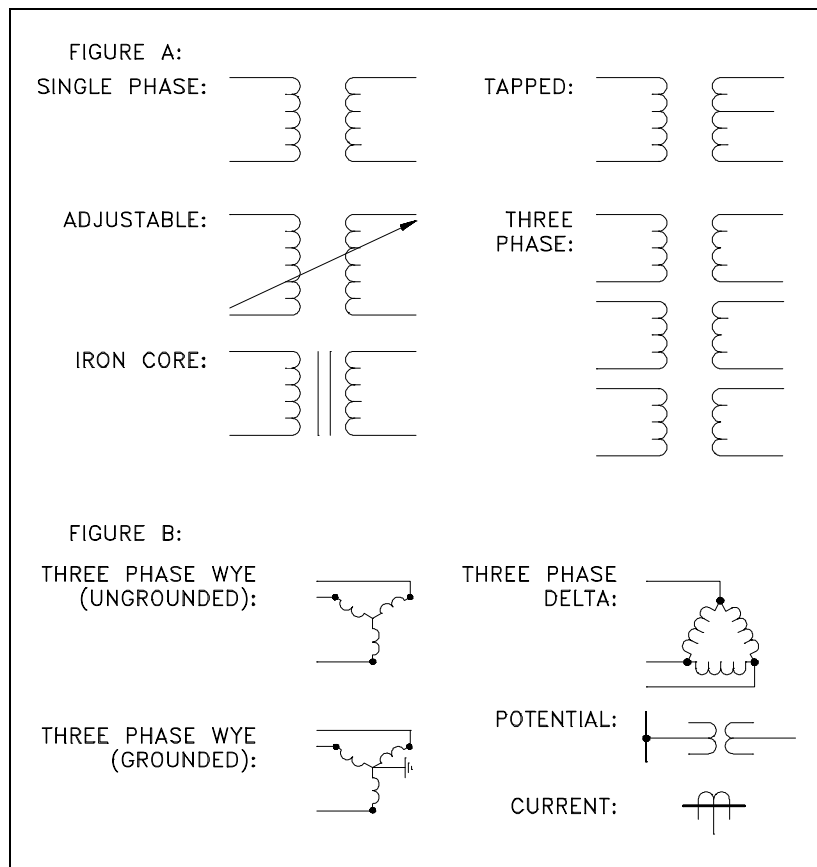


Figure 1 Basic Transformer Symbols

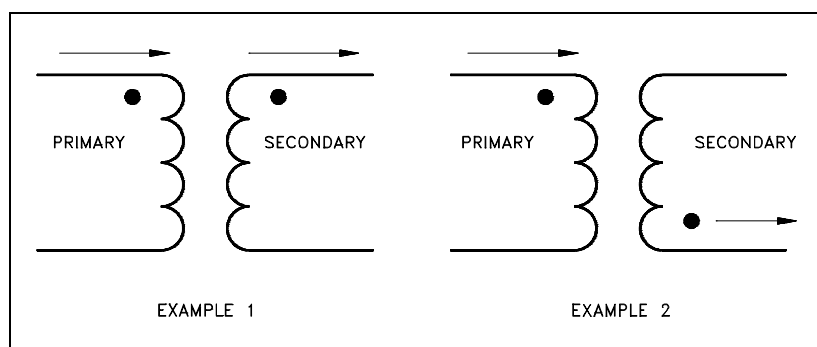


Figure 2 Transformer Polarity

On the primary side of the transformer the dot indicates current in; on the secondary side the dot indicates current out.

If at a given instant the current is flowing into the transformer at the dotted end of the primary coil, it will be flowing out of the transformer at the dotted end of the secondary coil. The current flow for a transformer using the dot symbology is illustrated in Figure 2.

Switches

Figure 3 shows the most common types of switches and their symbols. The term "pole," as used to describe the switches in Figure 3, refers to the number of points at which current can enter a switch. Single pole and double pole switches are shown, but a switch may have as many poles as it requires to perform its function. The term "throw" used in Figure 3 refers to the number of circuits that each pole of a switch can complete or control.

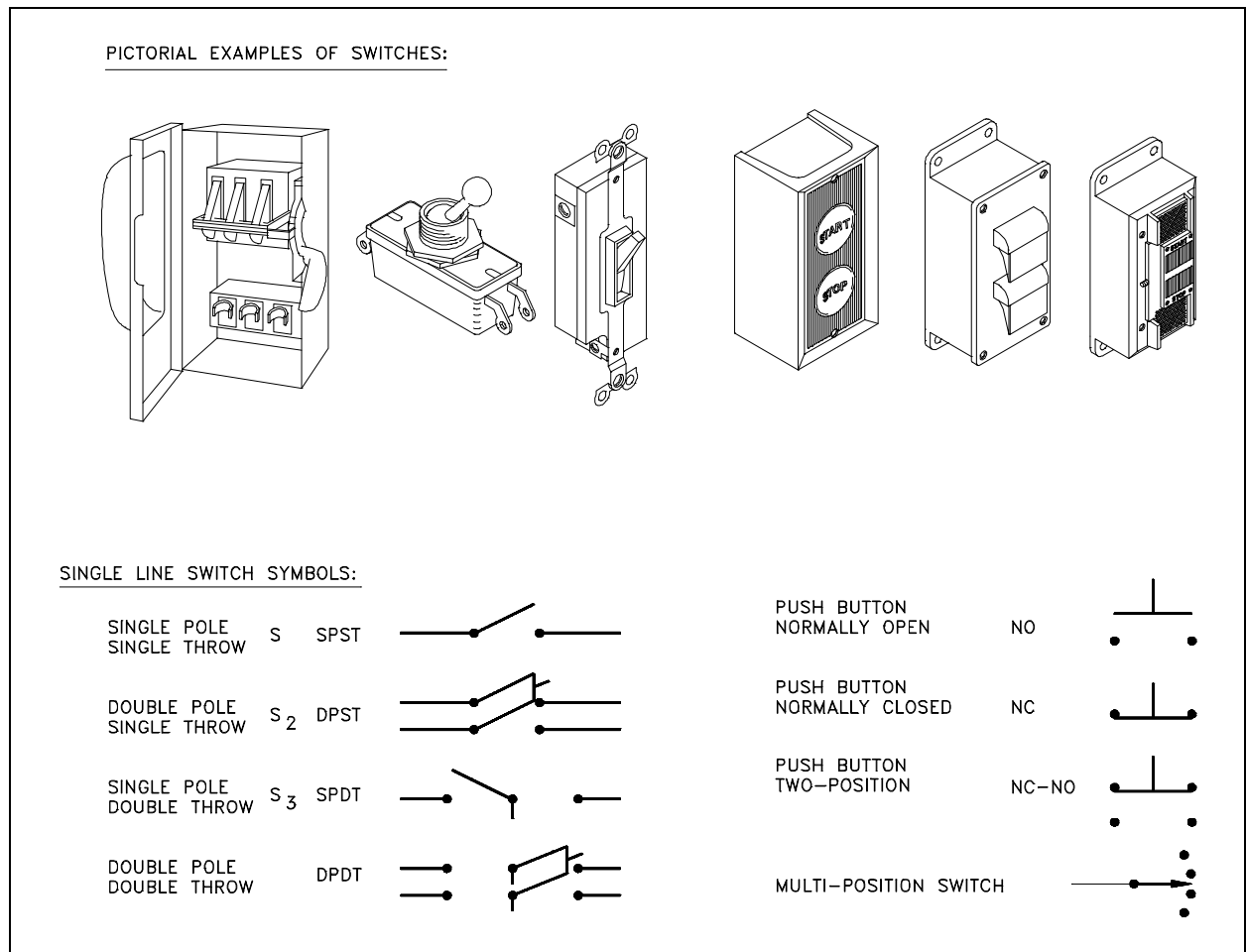


Figure 3 Switches and Switch Symbols

Figure 4 provides the common symbols that are used to denote automatic switches and explains how the symbol indicates switch status or actuation.





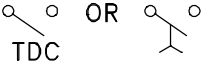
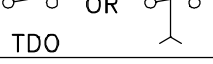
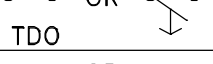
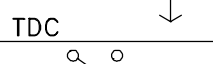







LIMIT SWITCH, DIRECT ACTUATED, SPRING RETURNED NORMALLY OPEN	
NORMALLY OPEN—HELD CLOSED	
NORMALLY CLOSED	
NORMALLY CLOSED—HELD OPEN	
OPEN SWITCH WITH TIME DELAY CLOSING (TDC) FEATURE	
CLOSED SWITCH WITH TIME DELAY OPENING (TDO) FEATURE	
OPEN SWITCH WITH TIME DELAY OPENING (TDO) FEATURE	
CLOSED SWITCH WITH TIME DELAY CLOSING (TDC) FEATURE	
FLOW ACTUATED SWITCH CLOSING ON INCREASE IN FLOW	
OPENING ON INCREASE IN FLOW	
LIQUID LEVEL ACTUATED SWITCH CLOSING ON RISING LEVEL	
OPENING ON RISING LEVEL	
PRESSURE OR VACUUM ACTUATED SWITCH CLOSING ON RISING PRESSURE	
OPENING ON RISING PRESSURE	
TEMPERATURE ACTUATED SWITCH CLOSING ON RISING TEMPERATURE	

Figure 4 Switch and Switch Status Symbolology

Fuses and Breakers

Figure 5 depicts basic fuse and circuit breaker symbols for single-phase applications. In addition to the graphic symbol, most drawings will also provide the rating of the fuse next to the symbol. The rating is usually in amps.

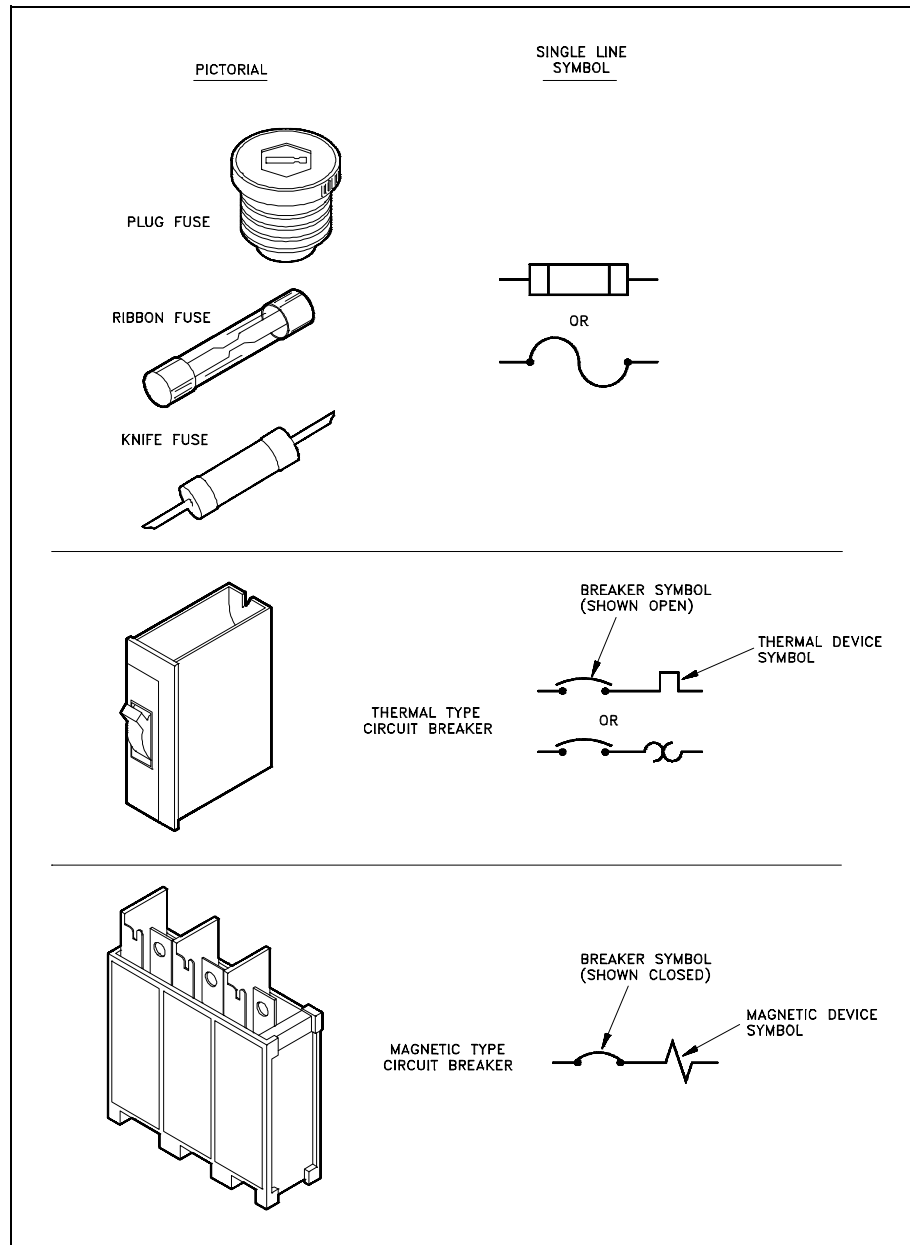


Figure 5 Fuse and Circuit Breaker Symbols

When fuses, breakers, or switches are used in three-phase systems, the three-phase symbol combines the single-phase symbol in triplicate as shown in Figure 6. Also shown is the symbol for a removable breaker, which is a standard breaker symbol placed between a set of chevrons. The chevrons represent the point at which the breaker disconnects from the circuit when removed.

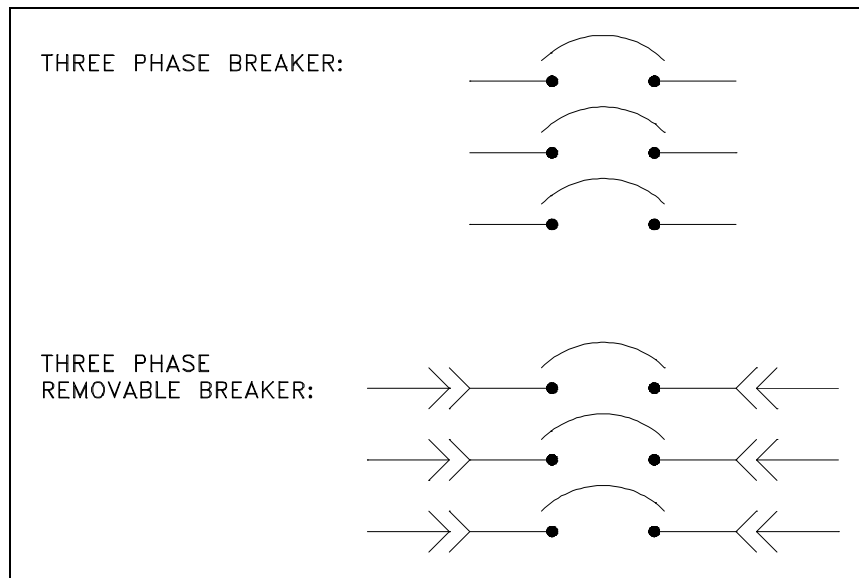


Figure 6 Three-phase and Removable Breaker Symbols

Relays, Contacts, Connectors, Lines, Resistors, and Miscellaneous Electrical Components

Figure 7 shows the common symbols for relays, contacts, connectors, lines, resistors, and other miscellaneous electrical components.

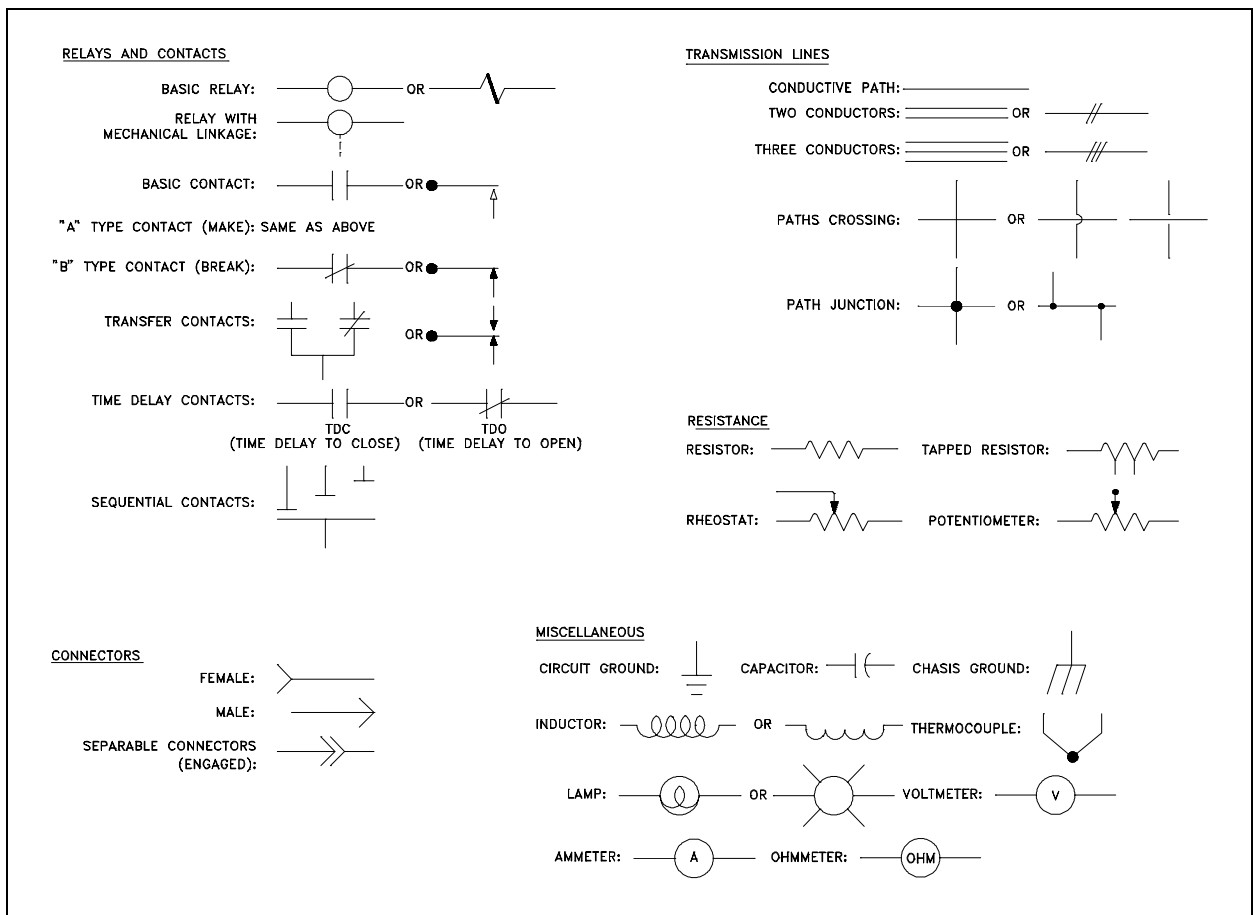


Figure 7 Common Electrical Component Symbols

Large Components

The symbols in Figure 8 are used to identify the larger components that may be found in an electrical diagram or schematic. The detail used for these symbols will vary when used in system diagrams. Usually the amount of detail will reflect the relative importance of a component to the particular diagram.

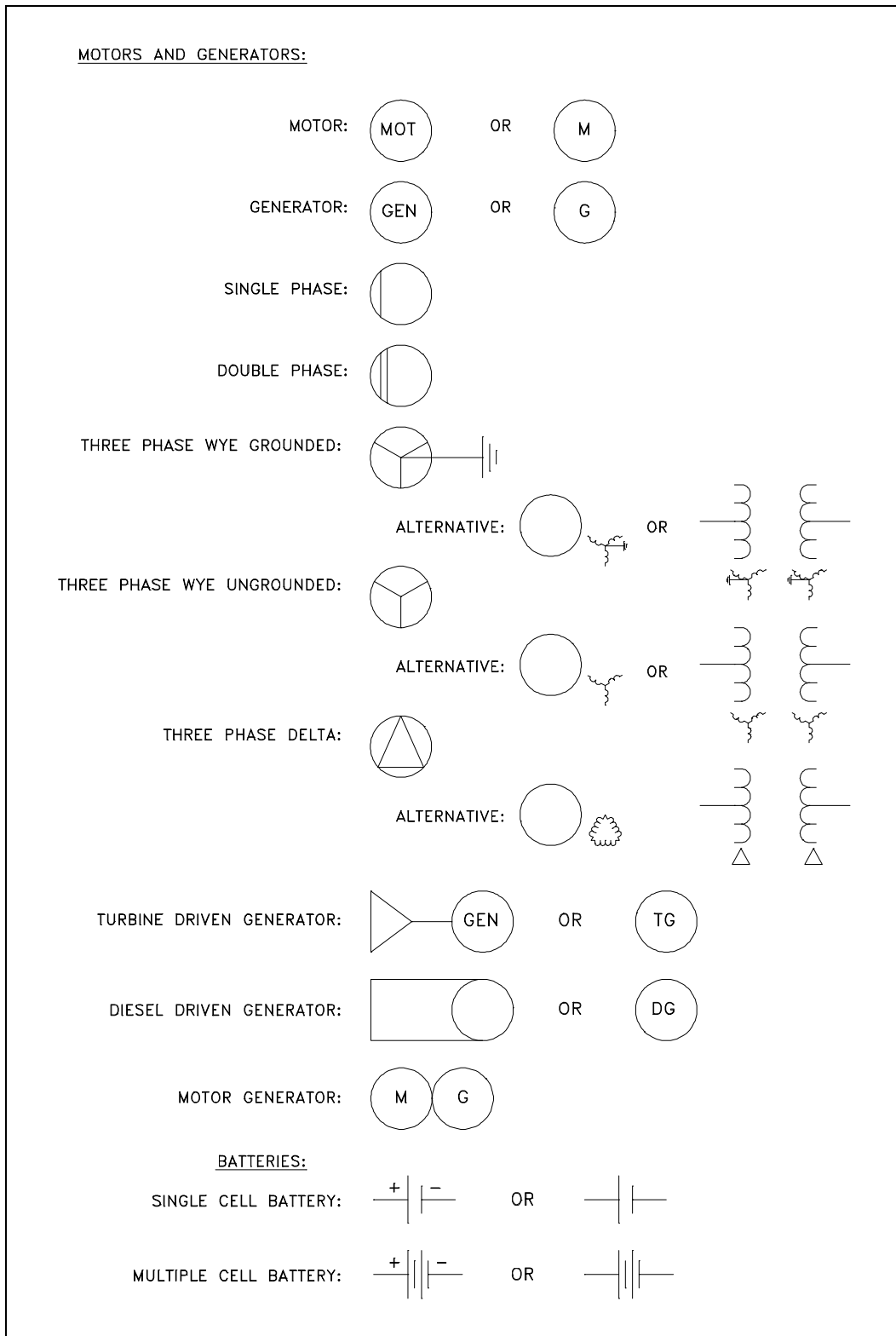


Figure 8 Large Common Electrical Components

Types of Electrical Diagrams or Schematics

There are three ways to show electrical circuits. They are wiring, schematic, and pictorial diagrams. The two most commonly used are the wiring diagram and the schematic diagram. The uses of these two types of diagrams are compared in Table 1.

TABLE 1 Comparison Between Wiring and Schematic Diagrams	
Wiring Diagrams	Schematic Diagrams
<ol style="list-style-type: none">1. Emphasize connections between elements of a circuit or system2. Use horizontal and vertical lines to represent the wires3. Use simplified pictorials that clearly resemble circuit/system components4. Place equipment and wiring on drawing to approximate actual physical location in real circuit	<ol style="list-style-type: none">1. Emphasize "flow" of system2. Use horizontal and vertical lines to show system flow3. Use symbols that indicate function of equipment, but the symbols do not look like the actual equipment4. Drawing layout is done to show the "flow" of the system as it functions, not the physical layout of the equipment

The pictorial diagram is usually not found in engineering applications for the reasons shown in the following example. Figure 9 provides a simple example of how a schematic diagram compares to a pictorial equivalent. As can be seen, the pictorial version is not nearly as useful as the schematic, especially if you were trying to obtain enough information to repair a circuit or determine how it operates.

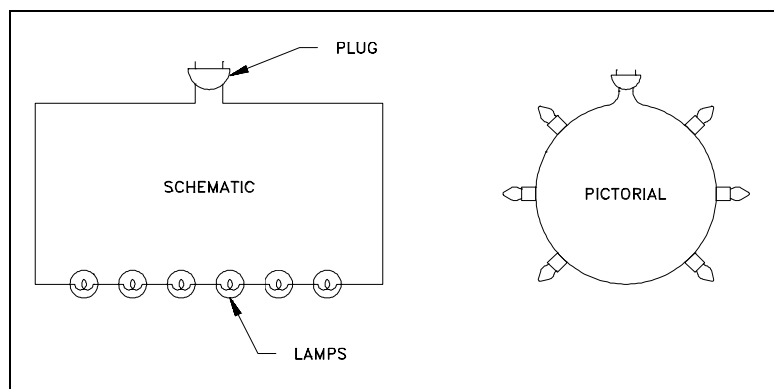


Figure 9 Comparison of an Electrical Schematic and a Pictorial Diagram

Figure 10 provides an example of the relationship between a schematic diagram (Figure 10A) and a wiring diagram (Figure 10B) for an air drying unit. A more complex example, the electrical circuit of an automobile, is shown in wiring diagram format in Figure 11 and in schematic format in Figure 12. Notice that the wiring diagram (Figure 11), uses both pictorial representations and schematic symbols. The schematic (Figure 12) drops all pictorial representations and depicts the electrical system only in symbols.

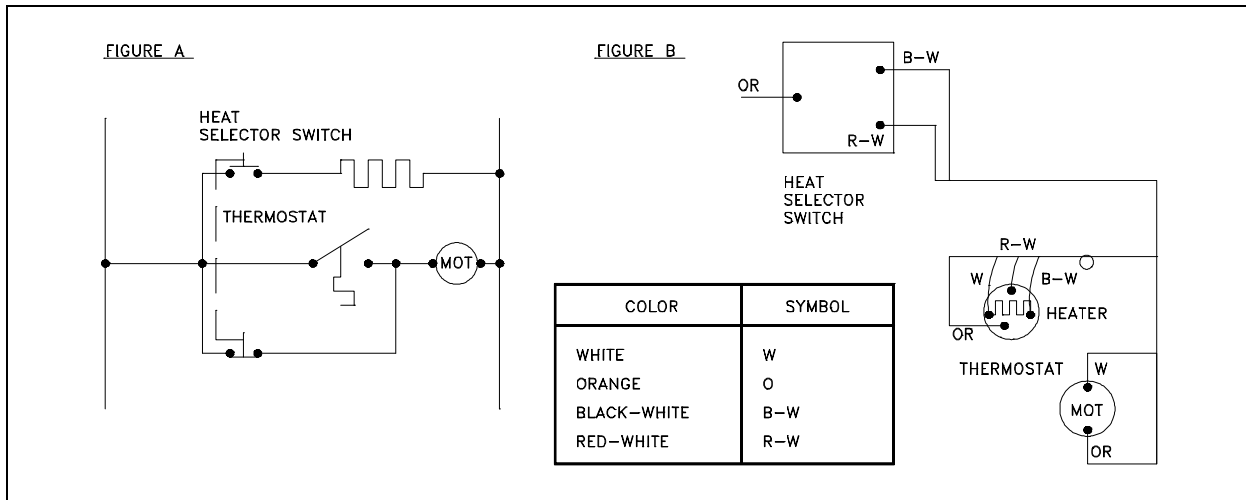


Figure 10 Comparison of an Electrical Schematic and a Wiring Diagram

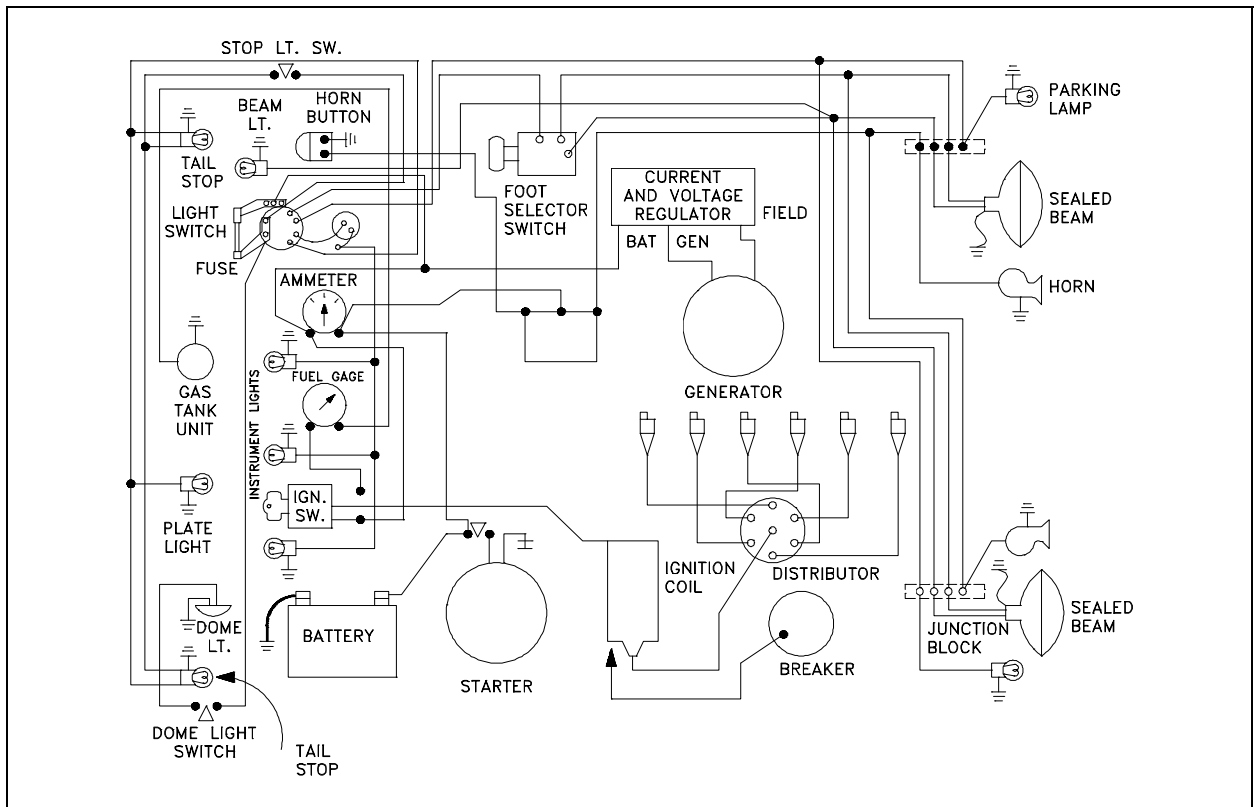


Figure 11 Wiring Diagram of a Car's Electrical Circuit

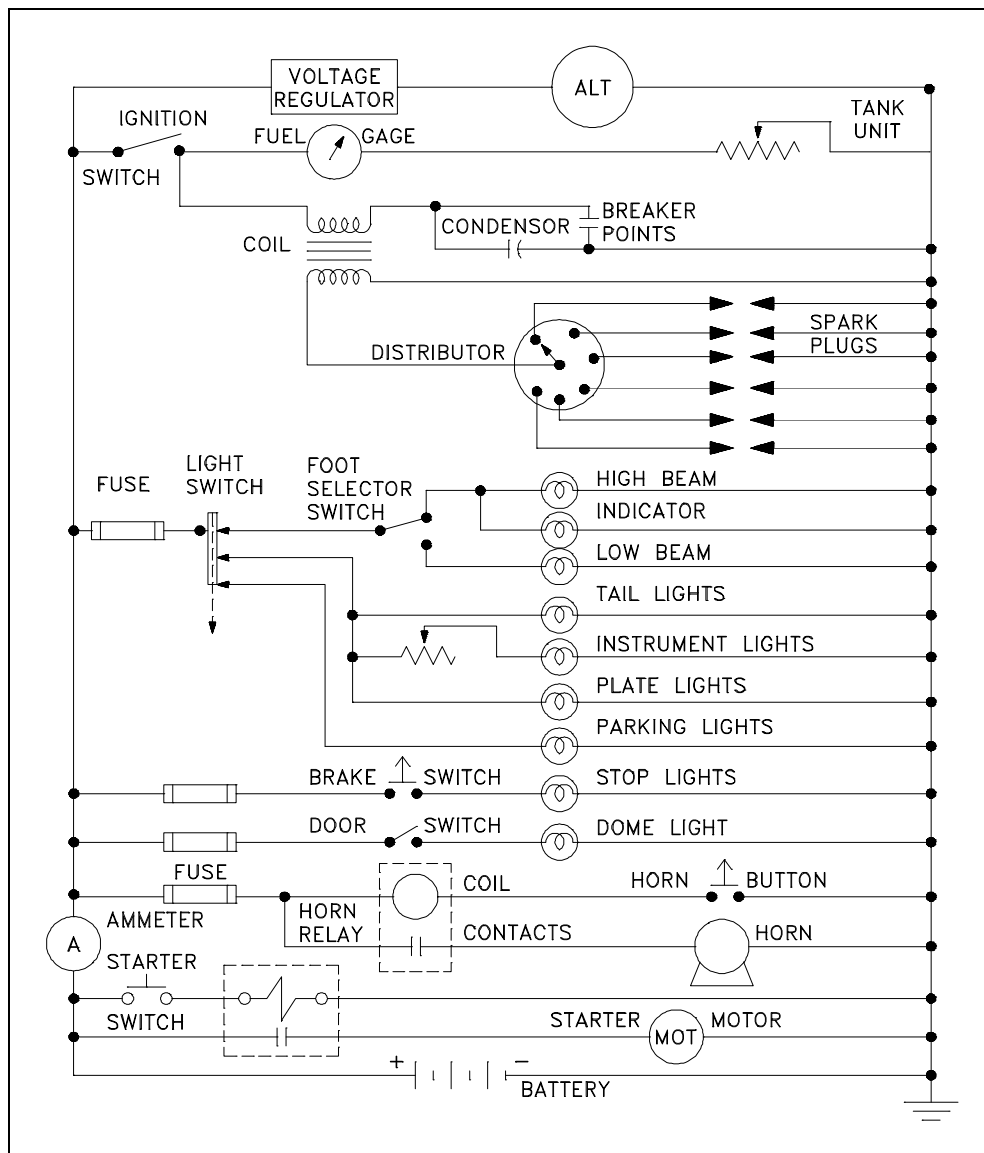


Figure 12 Schematic of a Car's Electrical Circuit

When dealing with a large power distribution system, a special type of schematic diagram called an electrical single line is used to show all or part of the system. This type of diagram depicts the major power sources, breakers, loads, and protective devices, thereby providing a useful overall view of the flow of power in a large electrical power distribution system.

On power distribution single lines, even if it is a 3-phase system, each load is commonly represented by only a simple circle with a description of the load and its power rating (running power consumption). Unless otherwise stated, the common units are kilowatts (kW). Figure 13 shows a portion of an electrical distribution system at a nuclear power plant.

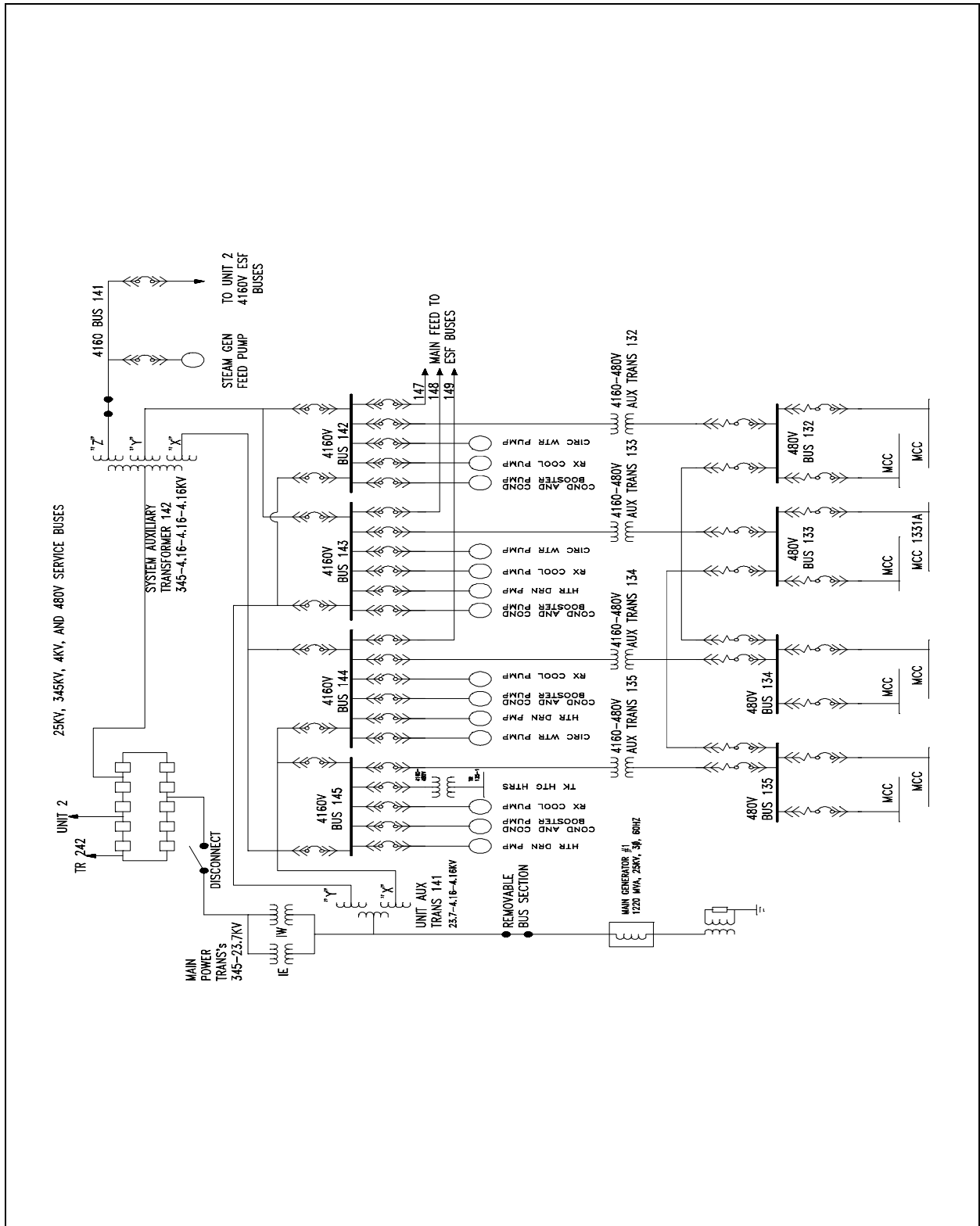


Figure 13 Example Electrical Single Line

Reading Electrical Diagrams and Schematics

To read electrical system diagrams and schematics properly, the condition or state of each component must first be understood. For electrical schematics that detail individual relays and contacts, the components are always shown in the de-energized condition (also called the shelf-state).

To associate the proper relay with the contact(s) that it operates, each relay is assigned a specific number and/or letter combination. The number/letter code for each relay is carried by all associated contacts. Figure 14 (A) shows a simple schematic containing a coil (M1) and its contact. If space permits, the relationship may be emphasized by drawing a dashed line (symbolizing a mechanical connection) between the relay and its contact(s) or a dashed box around them as shown in Figure 14 (B). Figure 14 (C) illustrates a switch and a second set of contacts that are operated by the switch.

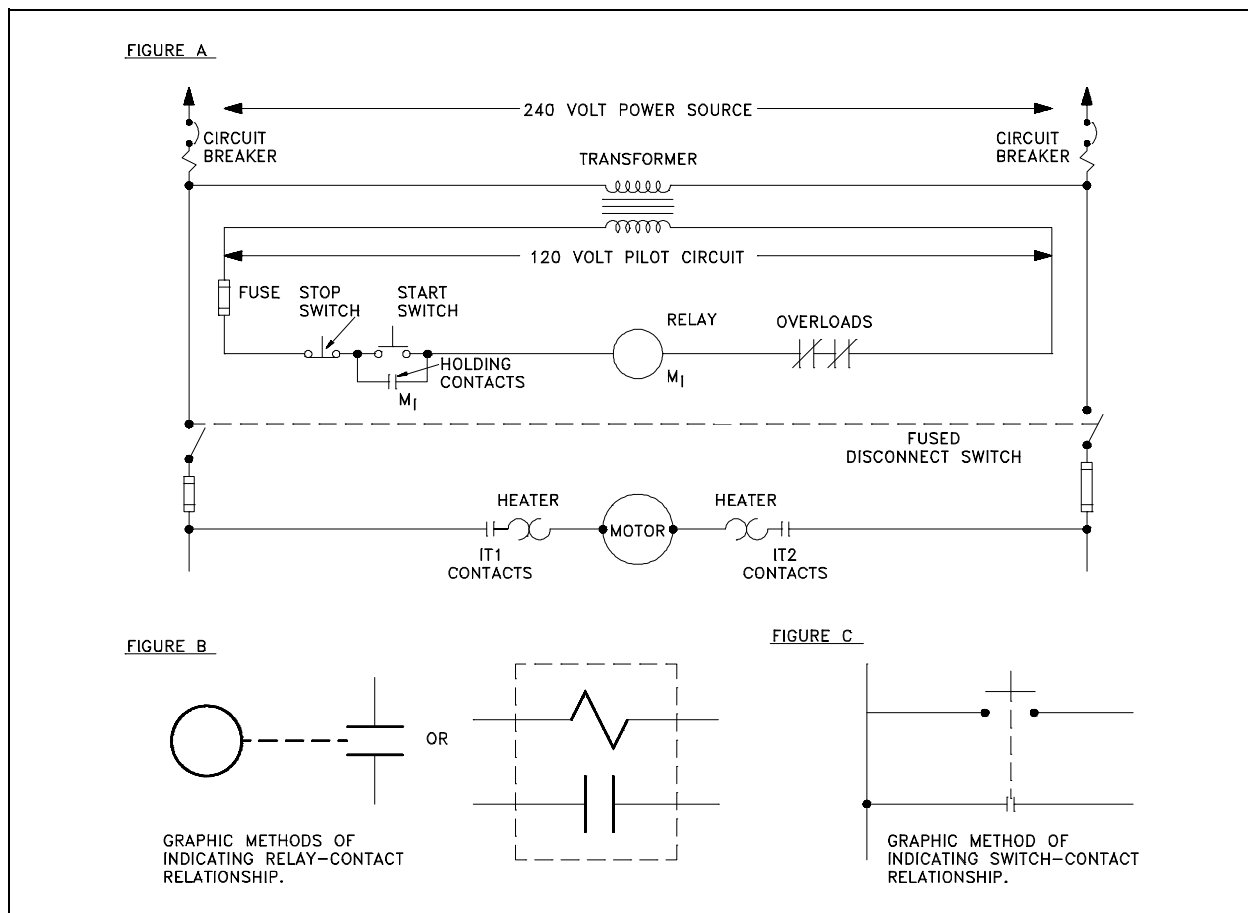


Figure 14 Examples of Relays and Relay Contacts

When a switch is used in a circuit, it may contain several sets of contacts or small switches internal to it. The internal switches are shown individually on a schematic. In many cases, the position of one internal switch will effect the position of another. Such switches are called *ganged* switches and are symbolized by connecting them with a dashed line as shown in Figure 15 (A). In that example, closing Switch 1 also closes Switch 2. The dashed line is also used to indicate a mechanical interlock between two circuit components. Figure 15 (B) shows two breakers with an interlock between them.

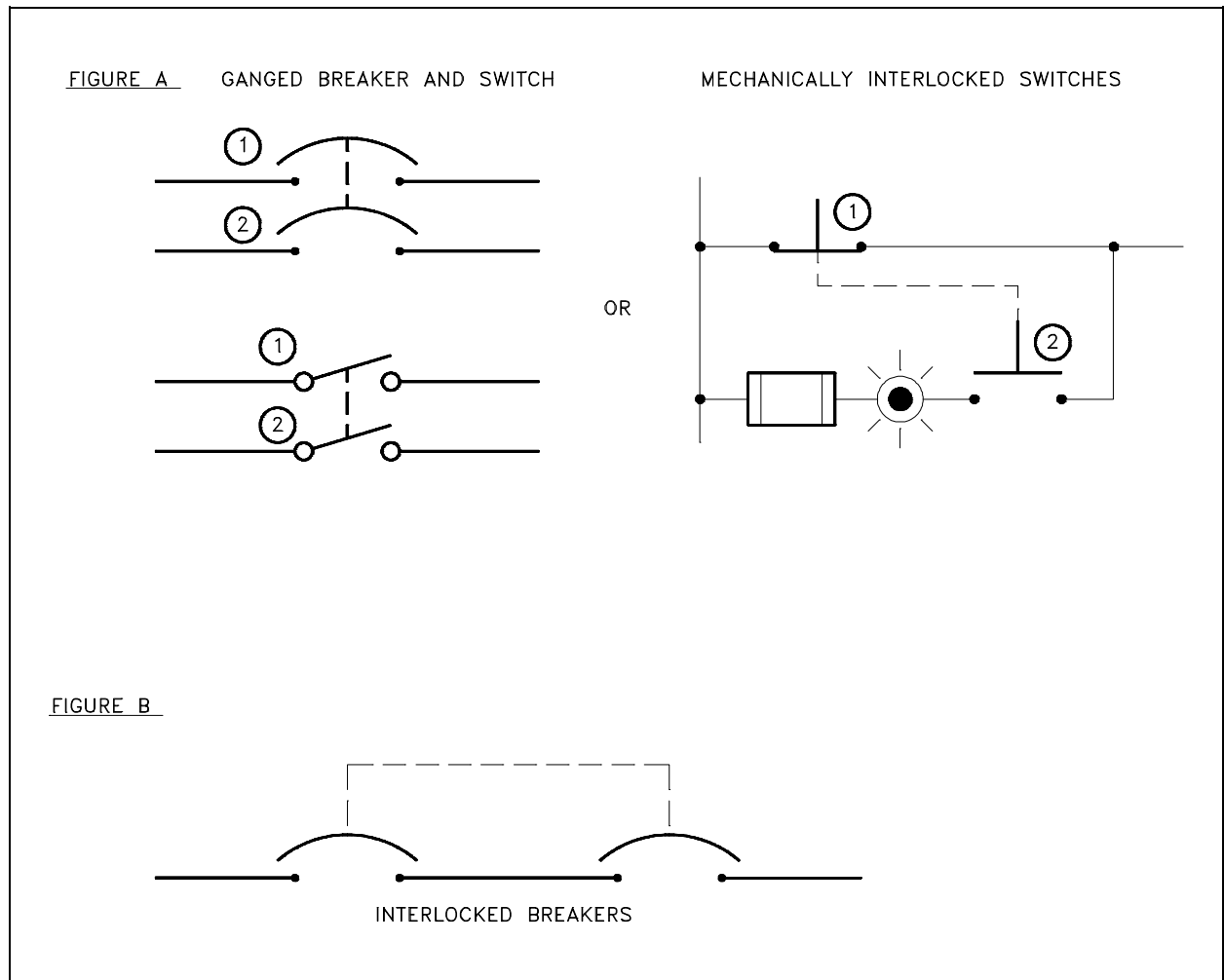


Figure 15 Ganged Switch Symbology

In system single line diagrams, transformers are often represented by the symbol for a single-phase air core transformer; however, that does not necessarily mean that the transformer has an air core or that it is single phase. Single line system diagrams are intended to convey only general functional information, similar to the type of information presented on a P&ID for a piping system. The reader must investigate further if more detail is required. In diagrams

depicting three-phase systems, a small symbol may be placed to the side of the transformer primary and secondary to indicate the type of transformer windings that are used.

Figure 16 (A) shows the most commonly used symbols to indicate how the phases are connected in three-phase windings. Figure 16 (B) illustrates examples of how these symbols appear in a three-phase single line diagram.

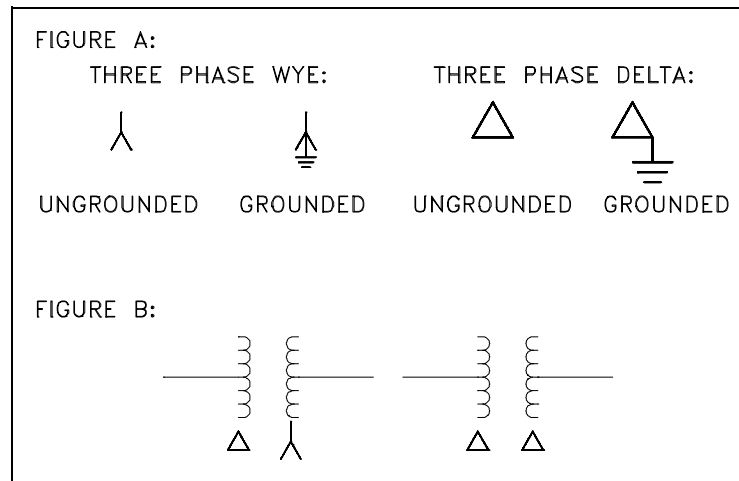


Figure 16 Three-Phase Symbols

Summary

The important information in this chapter is summarized below.

Electrical Diagrams and Schematics Summary

- This chapter covered the common symbols used on electrical diagrams and schematics to represent the basic electrical components.
- Polarity on a transformer is defined by dots placed on the primary and secondary windings. On the primary side, the dot indicates current in; on the secondary, the dot indicates current out.
- Switches, relays, and interlocked equipment commonly use dashed lines or boxes to indicate the relationship between them and other components.
- Electrical components, such as relays, are drawn in the de-energized state unless otherwise noted on the diagram.

ELECTRICAL WIRING AND SCHEMATIC DIAGRAM READING EXAMPLES

This chapter contains several examples that will help to build, through practice, on the knowledge gained in reading electrical wiring and schematic diagrams.

- 1.6 Given a simple electrical schematic and initial conditions, IDENTIFY the power sources and/or loads and their status (i.e., energized or de-energized).**
-

Examples

To aid in understanding the symbology and diagrams discussed in this module refer to Figure 17 and Figure 18. Then answer the questions asked about each. The answers for each example are given on the page following the questions.

Referring to Figure 17:

1. What type of diagram is it?
2. What is the rating on the fuses protecting the motor controller circuit?

Refer to the number at the far left to locate the following lines.

3. What is the component labeled ITDR in line 13?
4. Which lines contain limit switches?
5. Which lines contain pushbutton switches?
6. How many contacts are operated from relay 8CR?
7. What component is represented by the symbol on the far right of line 4?

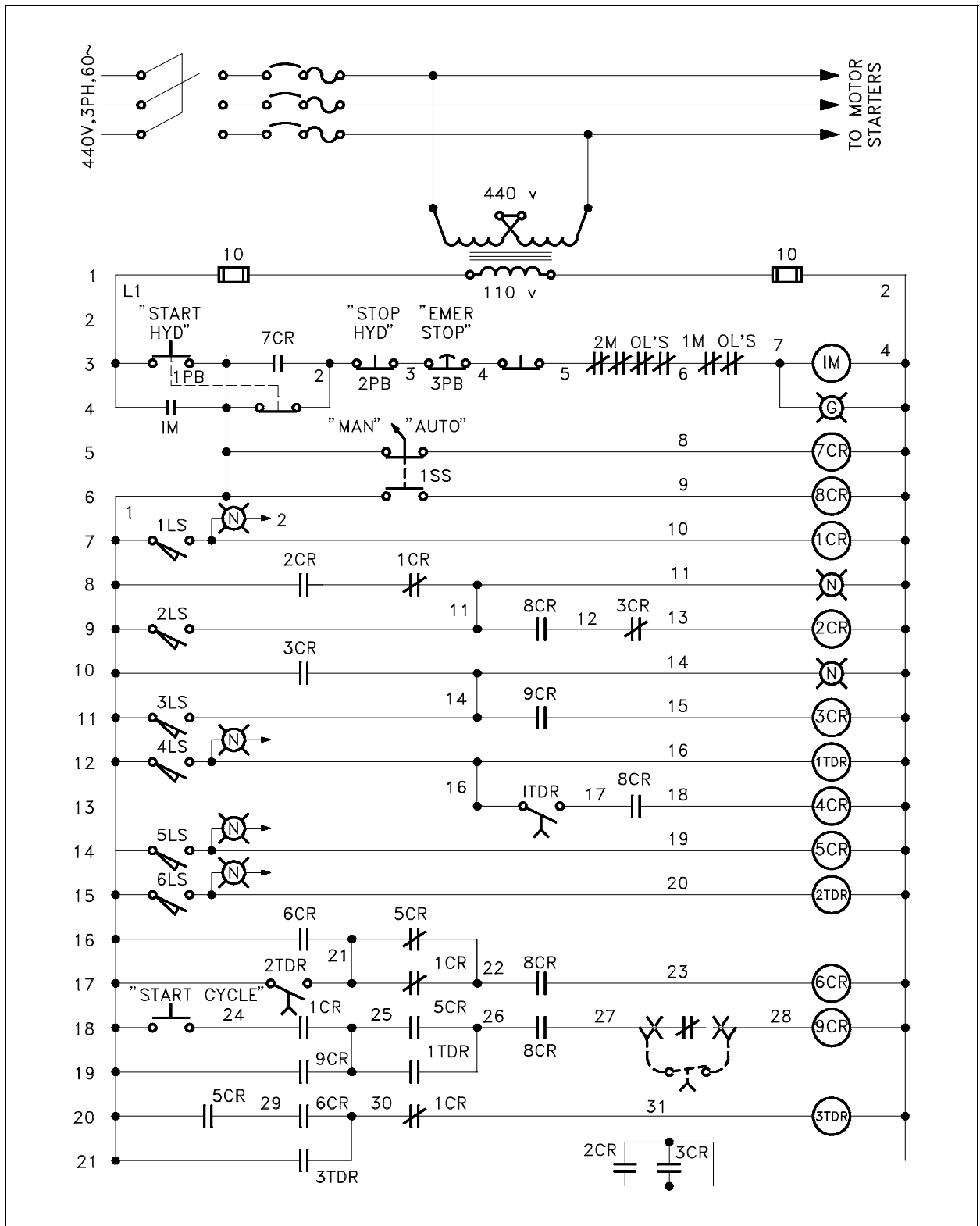


Figure 17 Example 1

Answers to questions on Figure 17.

1. Schematic
2. 10 amps
3. A time delay closing switch
4. Lines 7, 9, 11, 12, 14, and 15
5. Lines 3, 4, 5, 6, and 18
6. 4.
7. A green lamp

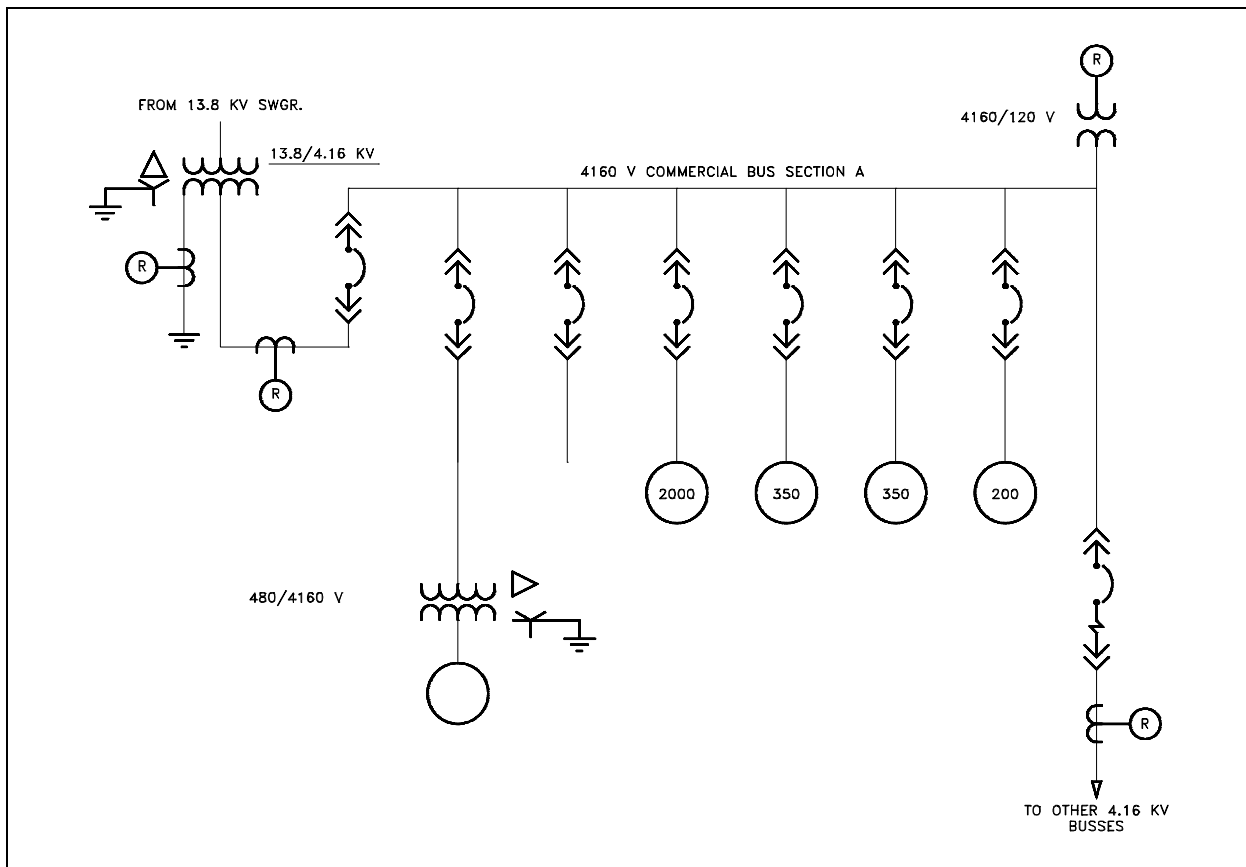


Figure 18 Example 2

Referring to Figure 18.

1. What type of diagram is Figure 18?
2. How many current transformers are in the diagram?
3. What type of circuit breakers are shown?
4. What is the voltage on the main bus?
5. What is the voltage entering the transformer in the lower left corner?
6. Classify the transformer in the upper left corner.
7. What is the component in the lower left corner?

Answers to questions on Figure 18.

1. System diagram
2. 3. If you said 4, the one in the upper right is a potential transformer.
3. Drawout type.
4. 4.16 kV or 4160 V.
5. 480 V.
6. Delta primary, grounded wye secondary.
7. (Emergency) diesel generator

Summary

The important information in this chapter is summarized below.

Electrical Wiring and Schematic Diagram Reading Example Summary

- This chapter reviewed the material presented in this module through the practice reading examples.

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